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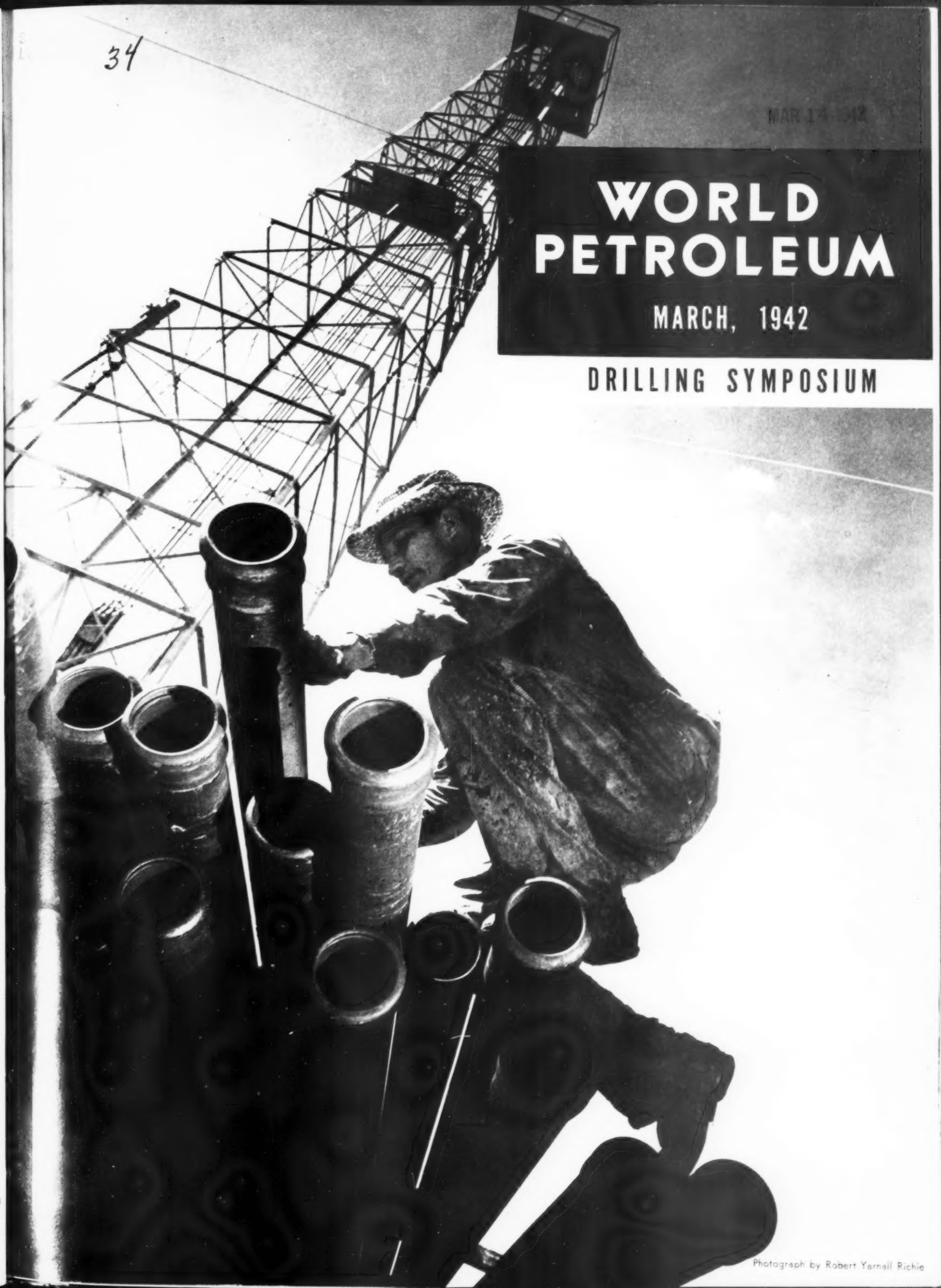
MARCH, 1942

DRILLING SYMPOSIUM



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THE MANAGEMENT PUBLICATION OF THE INTERNATIONAL PETROLEUM INDUSTRY

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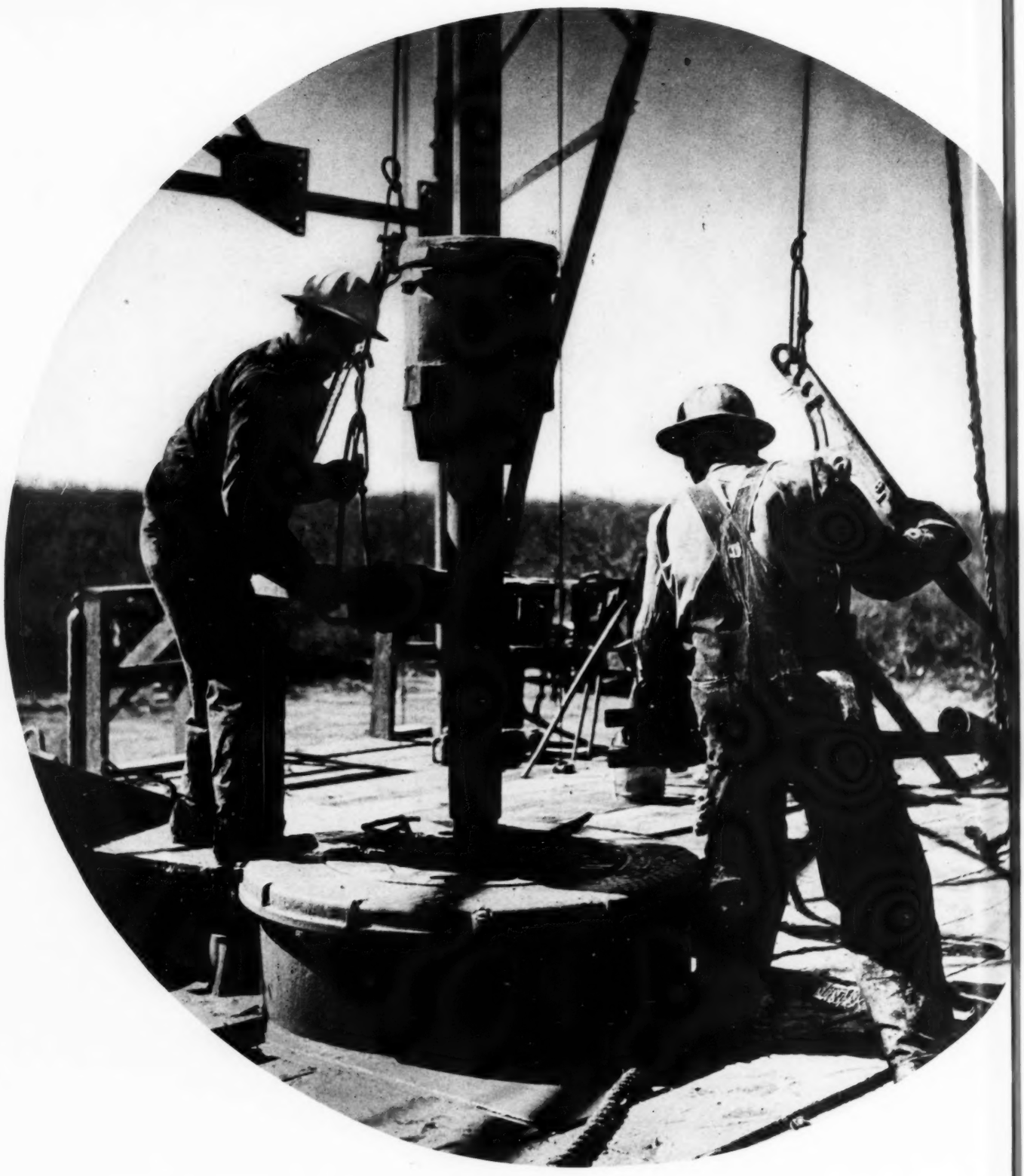


Drilling, particularly wildcat drilling must become the principal activity of the industry during the coming year if production is to be increased without depleting reserves. Despite government limitations on drilling equipment, many engineers look for increased wildcat drilling, particularly the slim hole and relatively shallow exploratory holes. Photo by Ulric Meisel.

EDITORIAL

CRITICAL BATTLE FOR OIL DRAWS NEAR

FROM the beginning of the present world war every important development has made it more and more evident that mastery of the air will finally decide the conflict. The military experts of the United Nations were slower than their adversaries to grasp this fact; indeed the Axis leaders seem to have mastered it before the struggle began and to have shaped their plans accordingly. The fate of Poland, the rout of French armies, the tragedy of Crete, the loss of battleships at Singapore, and Japan's stunning successes in the Pacific have driven home the lesson that aerial dominance is the primary requisite of success in offense or defense. Aside from numerical superiority the design of the planes, the power of their engines, the skill of their pilots and the quality of their fuel all are essential factors in deciding control of the air which in turn leads to total control. Discussion of the long debated question of ships versus planes has become meaningless. Naval might has its place in modern warfare but ships are helpless without a protecting cover in the air. Machines of vast destructive power have revolutionized land fighting but all this mechanized equipment is unavailing unless attended by overpowering strength above.

Irrespective of their specific functions and relative importance however, today's effective instruments of destruction all have one common denominator. On land or sea or in the air they depend alike upon the products of petroleum for their operation. Oil more than ever has become the decisive factor in the conflict that has engulfed the world. It is decisive not only because of the essential uses that it serves; among the material elements affecting the final decision it is the one above all others in which the Axis powers have been at a disadvantage which must be remedied if they are to retain a chance for ultimate success. This too is a truth which the master minds of Totalitarianism apparently have realized much more clearly than those who are arrayed against them. It becomes increasingly clear day by day that the next phase of the conflict, a phase already well developed on one side of the globe, is to be a desperate drive by the aggressors to gain control of great reservoirs of oil which will meet the utmost requirements of the Axis for future operations. The stake involved is so great, its bearing upon the subsequent course of the war is so evident that the Allies must exert a superhuman effort if need be to thwart the move. To roll back the attack now being prepared will prove in all probability to be the turning point of the war.

When Hitler surprised the world by his assault on the Soviet Union in June of last year the explanation most generally advanced was a purpose to gain control of the food supplies of the Ukraine and the oil of the Caucasus. While these considerations undoubtedly weighed in the decision it was pointed out in these pages at the time that the drive against Russia was properly to be regarded as part of a much broader strategic plan, no less in fact than an enveloping move against allied forces guarding Suez and its approaches from both directions. As was then explained, even though Nazi armies gained early and full control of the Apsheron peninsula possession of its rich petroleum fields would not provide a full solution of Germany's oil problem. Transportation difficulties would continue to hamper the movement of oil overland while other avenues were blocked so long as the British fleet remained in the Mediterranean. Once it became possible to penetrate through Syria and Iraq in a westward approach to Suez, combined with a strong eastward advance through Libya, the closing of the pincers upon that vital point in the Empire life line would drive British naval forces from the eastern Mediterranean and make it possible to open water routes which alone could solve completely the oil problem of the Axis powers. Oil then could move by ship from the Black Sea, and possibly from Iraq and Egypt as well, to Italian and other Axis-controlled ports whence it could easily be distributed to the parts of the Nazi dominated continent where it was needed.

Significant straws indicate that active preparations for such a concentrated attack are now in the making. The tenacity with which the Germans are battling to retain possession of the Crimea while giving ground on the more northerly sections of the Russian front is one of these. The massing of troops along the Turkish border with mechanized equipment and other preparations, which are alleged to include the laying of a pipe line to the very boundary of Turkey, point in the same direc-

tion. The comparative inactivity of the Luftwaffe gives credence to the theory that its ships are being overhauled and their numbers augmented while supplies of fuel are being accumulated. Not less significant perhaps is the strong reinforcement of Gen. Rommel's African army which has enabled him to recapture the ground previously lost to the British and to approach the western border of Egypt.

Much of the success of Hitlerite strategy in the past has come from its employment of the element of surprise, from the use of methods against which his adversaries had no adequate preparation, from attack in unexpected directions. But the great strategic objectives remain unchanged and one of these that is clearly essential to realization of the grand plan of Axis domination is to break the grip of the Allies on the Mediterranean area commanding the road to the East and to remove the handicap of inadequate supplies of oil. The drive for this vital advantage is inevitable and in view of all conditions it must be undertaken soon even though its coming cannot be concealed in usual Nazi fashion. The losses already sustained by the anti-Axis group have doubled or trebled the magnitude of their remaining task. Failure to stop a furious eastward thrust of Nazi legions would be a disaster to the Allies more serious in its bearing on the duration and outcome of the war than was the fall of France. Its strategic implications are so obvious that they must have been taken into account by the Allied leadership no less than by the Axis.

Thus the logic of the situation as well as the evidence of many recent developments points to a supreme effort on the part of Hitler to complete the conquest which has placed at his command the resources of most of the European continent by strengthening the one seriously weak spot in his armor, the lack of adequate supplies of oil. It is not necessary to assume an imminent shortage of oil for Axis military operations to explain such a move. The Nazi new order contemplates a future domination of the world that can be maintained only by armed force backed by all the essentials of continued military control. Oil holds a leading place among these essentials. An added incentive for a supreme drive toward the east is provided now by the swift success of the Japanese in over-running the southwestern Pacific with its vast resources of oil and other strategic materials. The chance to form a junction with the armies of Japan, to subjugate India and to claim a share in booty far richer than any he has gained in Europe is not likely to be overlooked by the man of Berchtesgaden whose visions of empire are as boundless as his own egotism.

PRACTICAL ASPECTS OF THE RESERVE PROBLEM

TODAY the question of reserves is engaging the serious attention of members of the oil industry, not because of concern as to the adequacy of immediate supplies but because rising demands upon production resulting from war conditions threaten to reverse the relationship of known underground supplies to current use if the influences encouraging exploration are stifled under official regulations applied to the industry. Study of the factors governing discovery reveals a close relationship between activity in exploration and the current price of crude oil. This is readily understandable since the incentive to oil search, with the preponderant risks involved, is lacking unless the probable return from a successful find offers a reasonable hope of profit. Under normal circumstances, with sharply rising demand, prices would increase to a point where they would stimulate more extensive exploration. With a lid upon prices imposed by the Office of Price Administration, holding them to the low levels of the past year while costs of production have risen by an estimated 15 to 20 percent, the venturing of investment in wildcat drilling is discouraged. To put it another way, prospecting is paid for out of funds remaining after other expenses have been met. If that remainder shrinks exploration naturally suffers to a greater or less extent.

Expansion of reserves comes from two sources. One is the extension of known fields. The other is wildcat drilling in entirely new areas. Of recent years additions have come more and more largely from the former and less proportionately from the latter. Since the deposits most easily found naturally are first developed exploration becomes steadily more expensive as it must be carried to more difficult locations and the drill must penetrate to greater depths to find oil. The number of dry holes drilled per unit of production rises from year to year; in other words the odds against recovery of the capital invested steadily lengthen. In a report prepared last month for the Petroleum Coordinator by a special committee of the Petroleum Industry War Council the importance of maintaining surveys and wildcat drilling at a high level is strongly set forth and the committee calls attention to another proposal which if adopted will place a further obstacle in the way of such exploration. This is the reduction advocated by the Secretary of the Treasury in the statutory depletion allowance which for more than twenty years has helped to cushion the losses sustained through unsuccessful drilling. The drain imposed by these failures is indicated by the fact that in the case of approximately one-third of all wells put down the cost of survey and drilling is a total loss. As the committee points out a wiser course in the present juncture would be to increase inducements for exploratory work rather than to reduce them.

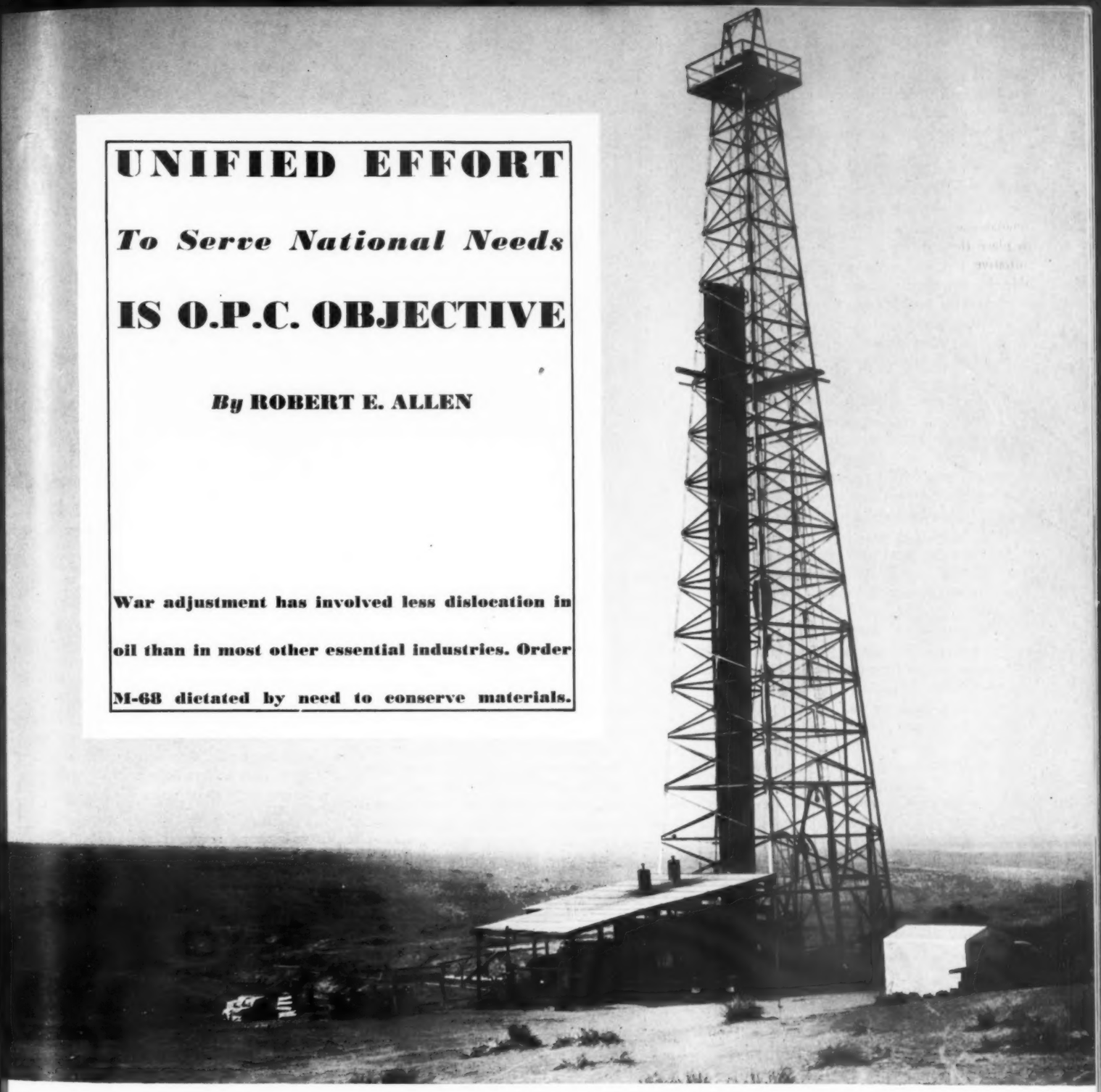
UNIFIED EFFORT

To Serve National Needs

IS O.P.C. OBJECTIVE

By **ROBERT E. ALLEN**

War adjustment has involved less dislocation in oil than in most other essential industries. Order M-68 dictated by need to conserve materials.



IN SELECTING an appropriate topic that may be of greatest interest and value to the production branch of the petroleum industry, nothing is more important at this particular time than open discussion of the tremendous responsibilities that, as a result of the present world conflict, rest squarely upon the shoulders of the men who are engaged in the production branch of the industry.

It has been gratifying, and it should be reason for justifiable pride, to know that a vast majority of the men responsible for conducting production activities are endeavoring to comply fully with the various recommendations, orders, and regulations issued by the federal government, the sole objective of which is to make certain that the powerful weapon of oil may be made available to this nation at war in such quantities as to assure a fully adequate and continuous supply of petroleum and its products on a sustained basis, not for the first year of the war alone, nor for the second year, but for each year until we achieve the victory that represents the only conclusion of the present conflict that Americans are willing to contemplate even in thought.

Even after the brief three months since the first willful acts of aggression were committed against us in the Pacific on the morning of December 7, 1941, it is possible to trace the more or less rapid transition from the condition of momentary bewilderment with which the production branch of the industry received the declaration of war to the present attitude of resolution and under-

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standing with which production men are "buckling down" and doing an extraordinarily splendid job of accomplishing a lot with a little.

It is not intended to create the impression that there is complete unanimity of opinion regarding the dislocations and restrictions that have unavoidably resulted from the adjustments required to place the industry on a wartime basis. The initiative and resourcefulness that so unmistakably characterize the oil man are not exactly the attributes that would permit him to like any part of a restrictive program that interferes with the normal peacetime activities to which he is accustomed and entitled.

It has been rather clearly demonstrated, however, that the men who have had occasion to register disapproval of many features of the program in which the greater part of the industry is now engaged with so much progress already discernible, are often the men who, for one reason or another, have failed to grasp or to be advised of the real purposes and objectives that are to be and must be attained by the industry in order to contribute in full measure to the successful prosecution of the war.

Frankly, much of the doubt and confusion with which these relatively few members of the petroleum industry view the entire subject of cooperative endeavor by the industry and the government as an aid in winning the war is occasioned by not knowing more about the real functions and purposes of the Office of Petroleum Coordinator for National Defense.

"What is the OPC? I know it is in existence now because it was that Office that told me I couldn't drill a well on my 2-acre lease. But when was it organized? I don't remember ever hearing much about it until after war was declared. And now, almost overnight, I'm told I can't do this and I can't do that. I've had to default on drilling offsets. I'm being discriminated against. I've got seven wells on my 40-acre lease but the fellow across the fence has eleven wells on his 40 acres and I am being drained. I've got a 20-acre lease with four wells on it and an 8-acre lease with only one well on it and yet I'm told I can only put a pumping unit on one of the four wells on the 20-acre tract but I can also put a pumping unit on the well on the 8-acre tract. What kind of logic is that? What's it all about?"

These are not hypothetical questions nor are they foolish questions. They are only samples of the many questions that operators have been asking. They are fairly obvious questions that any man might well ask who has unfortunately been more or less in the dark concerning the preparations that were first begun nearly a year ago by the federal government to meet the need for strong, unified action by the petroleum industry in marshaling its full strength for the purpose of providing a steady stream of fuel and lubricants for the countless number of implements of warfare, both on the field of battle and in the factories and shipyards at home.

Initial impact of M-68 on oil men operating under such varied conditions as are of West Virginia is now resolving

It is perhaps advisable, therefore, to preface the discussion of current problems that confront the production branch of the industry by reviewing briefly the manner in which the Office of Petroleum Coordinator for National Defense came into being, the purposes for which it was formed, and the methods whereby these purposes have been and are being fulfilled. By thus emphasizing the foundation whereon the work of the office is directed solely by the all-important consideration of how to contribute most effectively to the common defense of the nation, it is hoped that the value of such an agency to the petroleum industry itself may be more fully recognized.

The fact that many oil men, even those who recall the incident vaguely, are surprised to learn that the post of Petroleum Coordinator was created in May, 1941, nearly a year ago, serves to indicate the passing interest with which busy men often herald seemingly unimportant events.

The lack of general awareness in the industry as a whole of the formation and early activities of the Office of Petroleum Coordinator was further occasioned by the fact that very few of the earlier recommendations and regulations issued by the Office so directly affected the rank and file of the industry as have the restrictive measures that were invoked soon after the declaration of war.

Working in conjunction with the Office of Production Management (now succeeded by the War Production Board), the Office of Petroleum Coordinator assisted in formulating the earlier orders that pertained to the granting of priority ratings and other measures that were required in the petroleum as well as in nearly all industries as a result of the general shortage of steel and other critical materials.

Yet so efficiently did the manufacturers of equipment utilized by the petroleum industry busy themselves in meeting the newly developed emergency that only a relatively few operators in the oil and gas fields of the nation were conscious of the impending shortages of supplies and materials. Consequently, there was little occasion for the man in the field to do more than reflect that "something is going on up in Washington."

Virtually the entire nation knew of the "curfew" ruling that required all service stations on the Atlantic Seaboard to remain closed from 7 P. M. to 7 A. M. during the summer months of 1941. Characteristically, perhaps, the Petroleum Coordinator was blamed personally for nearly everything connected with the very real threat of shortage that existed as a result of the loan of tankers to the British. Strangely enough, the entire incident left the petroleum industry still more or less oblivious to the existence of an agency that was busily engaged, even last summer, in developing the details of the program that so speedily was invoked following the actual outbreak of hostilities.

The post of Petroleum Coordinator and the authority whereby the agency known as the Office of Petroleum Coordinator for National Defense (usually referred to as the OPC or merely the Office of Petroleum Coordinator) were first created and conferred on May 28, 1941, in a letter written by President Roosevelt to Hon. Harold L. Ickes, Secretary of the Interior. The aims and objectives of the Office of Petroleum Coordinator were admirably stated by the President in his letter, from which the following excerpt is taken:

...nd in off-shore drilling in California, the bayous of Louisiana and the gas fields ...of order, not yet complete, however.

"Recent significant developments indicate the need of coordinating existing federal authority over oil and gas and insuring that the supply of petroleum and its products will be accommodated to the needs of the nation and the national defense program.

"The various phases of operation in the petroleum industry itself are numerous and complex. One of the essential requirements of the national defense program, which must be made the basis of our petroleum defense policy in the unlimited national emergency declared on May 27, 1941, is the development and utilization with maximum efficiency of our petroleum resources and our facilities, present and future, for making petroleum and petroleum products available, adequately and continuously, in the proper forms, at the proper places, and at reasonable prices to meet military and civilian needs.

"Some of the problems with which we are now confronted and which require immediate action are: The proper development, production, and utilization of those reserves of crude oils and natural gas that are of strategic importance both in quality and location; elimination or reduction of cross hauling of petroleum and its products and the development of transportation facilities and of methods by which more efficient use can be made of existing transportation and storage facilities; balancing refining operations to secure the maximum yields of specific products with full consideration for requirements, the most economical use of the raw materials, and efficiency of production and distribution; and the elimination of the drilling of unnecessary wells in proven areas and of other unnecessary activities and equipment."

The President's letter then outlined the functions and responsibilities of the Petroleum Coordinator, including the assemblage of vital information from, and the formulation of specific recommendations to, the states and their agencies, the petroleum and allied industries, the officers and agencies of the Department of Interior, and other appropriate federal departments and agencies.

Further in his letter, the President said, "It is also expected that you will consult with the petroleum industry and those industries which affect its functioning, to aid them in shaping their policies and operations in the discovery, development, production, processing, transportation, storage, distribution, marketing, consumption, and import and export of petroleum and petroleum products."

Concerning the machinery whereby the Petroleum Coordinator might effectively discharge the duties thus assigned him, the President's letter continued, "Within the limits of such funds as may be made available to you, you may employ necessary personnel, including a Deputy Coordinator whose appointment shall be approved by me and to whom you may make any necessary delegation of functions, and may make provision for necessary supplies, facilities, services and for actual and necessary transportation, subsistence, and other expenses incidental to the performance of their duties. You will, of course, make use of such statistical, informational, fiscal, personnel, and other general services and facilities as you now have available or as may be made available to you through the Office for Emergency Management or other agencies of the government."

Thus, evidencing almost prophetic vision of the more important problems that now confront the petroleum industry, did this far-sighted action of the President, many months in advance of the actual conflict, create the agency whereby the petroleum industry might be enabled to direct its energies in full cooperation with the federal government in the defense program.

As a further indication of the pattern whereby the policies and principles of the Office of Petroleum Coordinator have been carefully formulated to assure that the work to be done would be in full accord with the democratic principles of our form of government, it may be of interest to quote a portion of the letter written by Honorable Robert H. Jackson, Attorney General, on April 29, 1941, to John Lord O'Brien, General Counsel of the Office of Production Management. Although the letter pertains to the prorationing of materials to all industries, it should be of particular interest to the petroleum industry because of the important effect the curtailment of materials has had on the activities of the industry. The following paragraphs are from the letter:

"The marshaling of the nation's industrial assets for a maximum productive effort in the national defense will doubtless require the allocation of orders, the curtailment of some kinds of production so as to increase production in defense fields, and the establishment of priorities and price ceilings. Furthermore, many of these steps must necessarily affect the production of goods used to satisfy our normal needs, as well as the production of materials and implements used directly in our defense effort. Some of these acts if accomplished by private contract or arrangement within an industry and carried on for private advantage would probably constitute violations of the anti-trust laws. On the other hand, it is obvious that in the present emergency acts performed by industry under the direction of public interest and to achieve public ends, do not constitute violations of the anti-trust laws. In these circumstances the Department of Justice recognizes that business interests which are asked to comply with public plans for increasing production and preventing inflation are entitled to the cooperation of agencies of the government in eliminating any uncertainties which may exist as to the application of the anti-trust laws to their activities."

This direct, but simple, statement of the need for governmental supervision of the nation's industrial assets during the emergency and the reasons why private industry should not be burdened with the sole responsibility of assuring that its efforts are directed collectively to the best interests of the national defense should serve to explain, in part, the legal considerations that prompted the creation of an agency that would serve as an intermediary between the petroleum industry and the defense program, furthering the best interests of both insofar as possible.

To give further insight into the formulation of the policies by which the Office of Petroleum Coordinator was to be guided in its work, the following excerpt is taken from a letter written by Petroleum Coordinator Ickes on June 16, 1941,

to Honorable Robert H. Jackson, Attorney General, for the general purpose of outlining the activities of the newly formed agency:

"Moreover, I am particularly anxious, in fairness to the oil industry, that whatever action by the industry I may find necessary in connection with the future work of my office shall be initiated by my office and definitely reduced to writing in the form of recommendations or directions from this office to the industry. Furthermore, in order to avoid any possible misunderstanding on the part of either the public or anyone in the industry, I propose that these recommendations or directions be duly published in the Federal Register as provided by law and a duplicate original submitted to your Department as of the effective date of any such recommendation or suggestion.

"I anticipate that there will be numerous specific instances where I shall want to ask the oil industry to take action in order that costs may be kept down, oil and gas properly conserved, and the producing, transportation, refining and distributive facilities of the industry utilized at maximum efficiency. *It may also be necessary to take action to avoid imposing inequitable burdens upon small independent operators in the present emergency.*"

The liberty has been taken of italicizing the last sentence in the above paragraph in order to emphasize what may be considered to be one of the first principles of paramount importance that is weighed seriously in every action taken or decision made within the Office of Petroleum Coordinator.

Having perhaps a more direct bearing on the problems that have caused the greatest dislocation of normal activities within the petroleum industry, the following quotation from an early press release indicates the serious effort that has been made from the outset by the Office of Petroleum Coordinator to develop an effective system whereby necessary materials for the petroleum industry could be obtained with as little delay as possible.

"All applications for priority aid made by the petroleum industry for materials and supplies will be considered by the Petroleum Coordinator with regard to a broad general plan . . . for the most effective use of essential materials to maintain supplies of petroleum products in such a manner that neither the defense needs of the present nor the public needs of the future will be impaired or prejudiced.

"In order to expedite adjustment of the industry to an emergency condition which involved a limited supply of materials, five district offices of the Petroleum Coordinator (have been) established and (are) available to receive applications from the industry for transmission to the Petroleum Coordinator's office."

In addition to the establishment of the five district offices, strategically situated at New York, Chicago, Houston, Denver, and Los Angeles, the Petroleum Coordinator has designated from time to time the appointment of committees and councils composed of members who are representatives of the petroleum industry itself, to consult with and advise the Petroleum Coordinator. Accordingly, each of the five districts now has industry committees representing each major division of the industry. Composed of members whose interest and experience are centered in the geographic area embraced within the respective districts in which these committees serve, the specific problems and characteristics of the various oil and gas fields and other elements of the petroleum industry throughout the nation are thus made known to the Office of Petroleum Coordinator.

Coinciding almost to the day with the formal declaration of war by the United States, the Petroleum Industry War Council was organized, composed of 66 members (now increased to 72) representing the petroleum industry. Thus, still more adequate assurance was provided that the interests and needs of the petroleum industry would be accorded serious consideration.

More recently, another body, representing in this instance the oil producing states directly, was organized. This group, known as the National Conference of Petroleum Regulatory Authorities has the general purpose of presenting to the Petroleum Coordinator the views of the various states represented and of effecting the full cooperation of the states in the national defense program.

Beginning January 1, 1942, the Petroleum Coordinator found it necessary, in the national interest, to issue monthly certifications to the various oil producing states recommending the maximum daily production rate that should exist in each state during the ensuing month.

The purpose of issuing the certified volumes to the states each month is to obtain gradually a better balanced participation by the states in meeting the national demand for petroleum. Whereas in normal peacetime each state has exercised the privilege of determining what quantity of oil should be produced within its boundaries, obviously, in time of war, the former haphazard participation by the states in supplying the nation's petroleum requirements would not provide the definite assurance of adequate supplies on a sustained basis that is so essential to the nation's welfare.

Perhaps the most concrete evidence of the reaction that gripped the petroleum industry upon the outbreak of actual war was the belief, on the part of a few states as well as many operators, both large and small, that it was their patriotic duty to open the oil wells of the nation and permit them to produce at maximum capacity in order to provide enough oil for the armed forces.

It is probable that the reaction was more or less a natural one, no matter how grossly in error it was. Possibly the appeal for a greater, more intensive search for new fields that has been issued so frequently in recent months has created the impression that the nation is confronted with a current shortage of crude oil. Irrespective of what the cause may have been, it must be emphasized that the urgent need for finding additional petroleum resources does not spring from a shortage of petroleum supplies in sufficient quantity to meet the needs of the immediate future.

The recognition that additions to the known supplies of petroleum must be made did not originate with the present national defense program. Petroleum economists have sounded the warning with increasing alarm during the recent years that have witnessed a steadily increasing consumption of fuel and lubricants as more and more automobiles, trucks, tractors, airplanes, and other mechanized units have come into use. Whether it is petroleum or some other irreplaceable, irreproducible natural resource, it is elementary to realize that a reserve that is consumed at a faster rate than additions to the reserve are made is steadily being depleted and will eventually be exhausted.

The present discussion is undertaken purposely without the benefit of the usual impressive statistics that indicate the number of years' supply of petroleum that may be recovered from our presently known reserves. It is not proposed to give the enemy any more information than he already has, unfortunately, concerning the resources of the United States. Let it be said, nevertheless, that the nation possesses petroleum supplies in quantities of such magnitude as to give the enemy little cause for rejoicing in his anticipation that we may be unable to supply the needs of this nation and of the allied forces for as long as it takes to gain a victory. By the same token, let us resolve so to conduct our business, as oil men, as to conserve our present supply of petroleum and add to it in every way we can, so that we may say to the nation, with confidence, that we can supply the requirements of the war indefinitely, if need be, and still have enough remaining to serve our needs after the war is over.

Perhaps the first real indication to the production branch of the industry as a whole of the fact that we are all in a war all the way came with the issuance of Conservation Order M-68. As nearly every operator in the nation knows by now, this is the order that prohibits the drilling of oil wells on spacing of less than 40 surface acres and of gas wells, in general, on less than 640 surface acres. In addition, limitations are placed on the number of wells that may be equipped with pumping or other artificial lifting equipment.

Cable tool operations in New York state far removed from the conditions surrounding off-shore drilling as pictured on a preceding page, are equally subject to the provisions of the 40-acre spacing rule issued as M-68.

These are the things in general that the order limits and these are the provisions that nearly everyone has looked at first. Not many, even now, have bothered to read the order in full. Those who have read it fully permit themselves to become confused. For example, the order states in one paragraph that materials required for the maintenance or repair of property or equipment or as operating supplies may be obtained without limitation, within the definitions of those terms in Preference Rating Order P-98. This statement is purposely intended to include all wells producing as of December 23, 1941, regardless of status and all wells drilled, completed, or converted from flowing to pumping or other status subsequent to the above date, provided the work conforms to the order. Yet many operators have interpreted the provisions of a later paragraph in the order, which limits the number of wells that may be equipped with pumping or other artificial lift equipment, as counteracting the previous provisions.

Likewise, the order specifies that no restrictions are placed on the use of materials required in carrying out secondary recovery operations. Many operators have asked whether the spacing restrictions in other paragraphs counteracted the provisions of the paragraph pertaining to secondary recovery operations. The answer is no. Obviously, an operator engaged in the efficient operation of a secondary recovery program that in itself represents efficient attainment of maximum recovery to an advanced degree needs to drill both input and producing wells at locations that are dictated by the program itself.

It is believed that it is more generally recognized now that Conservation Order M-68 is not the inflexible, ill-advised instrument that it was at first believed by many to be. As more operators have come to realize how really critical the shortage of steel and other finished materials is, they understand the need for and appreciate the existence of a regulation that endeavors to allocate such quantities of these materials as are available to the petroleum industry on as equitable and far-reaching basis as possible.

It has been a more or less obvious reaction, probably, when a few individuals and organizations in the oil business have assumed that the Office of Petroleum Coordinator was created for the purpose of throttling the petroleum industry and of preventing its proper development. Nothing could be further from the truth, as the above review of the OPC's organization has indicated.

The petroleum industry has been recognized as a defense industry by the federal government and permitted to continue its normal functions during war time with less dislocation and rearrangement than almost any other essential industry.

At the same time while the Office of Petroleum Coordinator is considered a branch of the wartime government, charged with the responsibility of assuring the nation an adequate continuous supply of petroleum products on a sustained basis for all military and essential industrial and civilian requirements, the petroleum industry should remember that the Office is also working to its best interests as well — inasmuch as the sole consideration guiding us all in the months to come is how we may best serve our country.

ADEQUATE U. S. RESERVES

Await Stimulation Of Incentive To Drill

By A. I. Levorsen

Minimum Regulation Limiting Profit Motive in Exploration Drilling Will Assure Discovery of Substantial Reserves that May Reasonably be Supposed to Exist in the United States.

MANY factors have contributed to the steady growth of the oil industry in the United States but none is more fundamental than its ability to maintain a continuing discovery of new supplies of crude oil. Not only has this ability been fundamental to its past growth, but any favorable outlook into the future of the industry must of necessity be predicated on a continuance of adequate discovery. Other industries may develop a residue of scrap material to cushion any extra demand or sudden loss of supply, but in our industry, consumption is complete and an emergency demand means either drawing on our savings of available reserves or upon making new discoveries sufficient to offset withdrawals.

The available known oil reserves, as has been well publicized, range somewhere between 18,000,000,000 and 20,000,000,00 barrels. Of this, only a part, possibly on the order of one-forth or one-fifth, is available for use during the next few years, leaving the remainder to be produced at progressively slower rates over a long period of years. This known reserve, which largely represents an excess of discovery over needs and which might be called our "savings account," is our first line of defense against any sudden increase in demand. Moreover, it represents the tangible results of the proration policies of recent years and amply demonstrates the wisdom of such action. The more severe the emergency requirements, the more reason to draw heavily on the known reserves. However, if this reserve should be drawn on too rapidly or beyond the rate of good production practice, it immediately sets up a condition which leads to ultimate waste in many fields and sound conservation would require that the rate of withdrawal not be so great as unnecessarily to reduce the ultimate quantity of the known reserve. In times of stress, it therefore is doubly important not to neglect the discovery factor in the economy of the industry As this is written, ideas of the requirements for the months and years immediately ahead are in a state of flux and vary for 1942 from a decrease of up to 35 percent to an increase of 1 to 15 percent over the 1941 requirements. However, emergency or not, the overall picture of the oil industry in the United States is that of expansion and the rate of this expansion is directly dependent on its continuing ability to replenish its reserves of crude oil by continuing discovery. In other words, the discovery problem has been and will continue to be with us with varying degrees of emphasis and importance, and will be fundamental to all planning of supply, price, quantity and availability.

The word "discovery" means to "get first sight or knowledge of something previously unknown or unperceived." In advance of physical discovery, our approach to the problem of discovery in the oil industry must be through our reason and our philosophy—chiefly geological—concerning the factors which influence the occurrence of oil and gas. The question naturally divides itself into two parts; first, do we have reason to be-

lieve there is oil and gas which remain to be discovered in amounts adequate to take care of national needs in the foreseeable future? In other words, is there something to discover, if we would? Second, how shall we get "first sight or knowledge" of it? Or, how shall the discovery be made? And particularly now, when it is necessary that it be made with the lowest cost in men, materials and effort. The problem resolves itself into something similar to that of little Johnnie and the cookie jar. If he feels certain the jar is full, he will keep on looking until he finally finds where the cook has hidden it. And so, if we feel assured of the presence of oil to be discovered, we too will keep on looking until we find it.

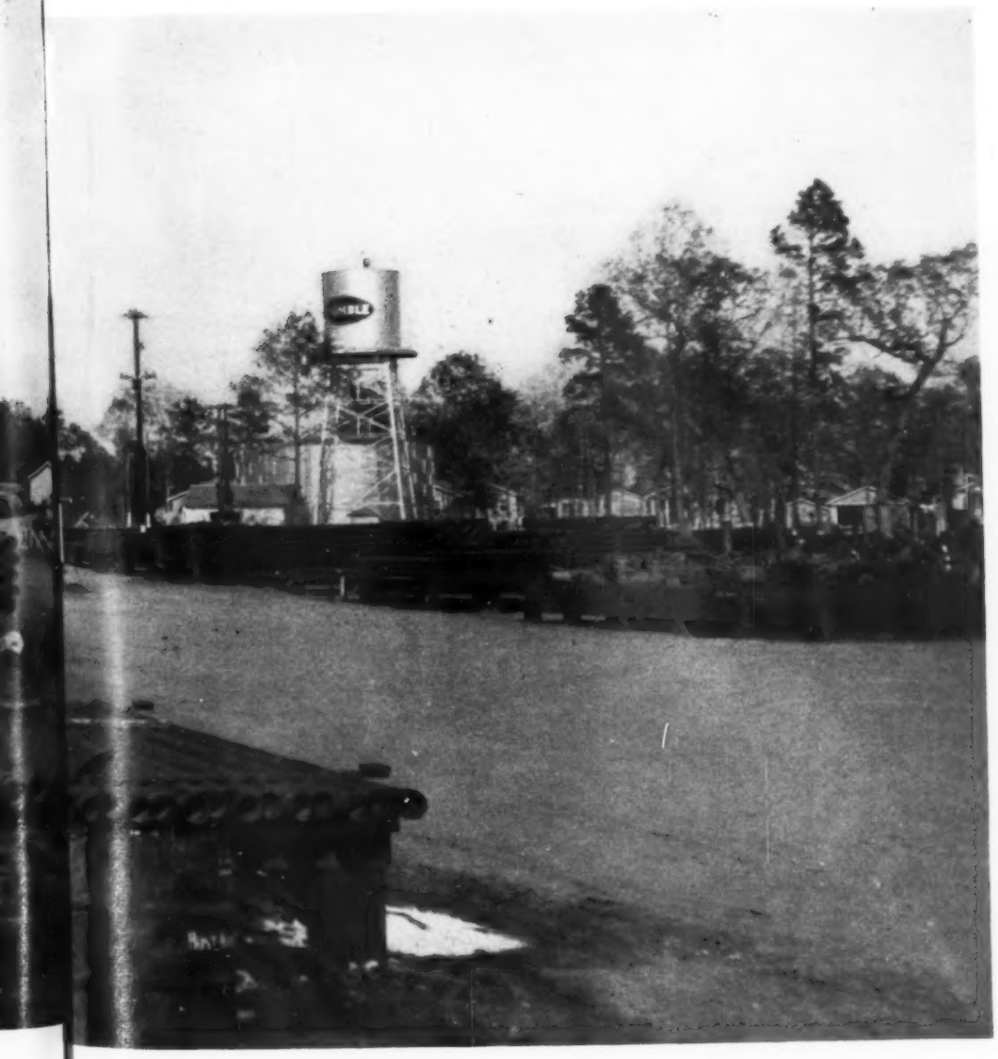
The answer to the first part of the problem surely must be "yes." Certainly there is nothing yet in the science of petroleum geology which limits the undiscovered reserves within the United States. It is true that we have produced much oil in the past, and in doing so have condemned much territory for further exploration, but at the same time we have expanded our understanding of the conditions under which oil occurs, the geology of the country, and the techniques of obtaining information, to such a point that the future appears to be even larger than the past, not only in spite of the discoveries of the past, but also because of them. The location of this undiscovered reserve might be divided into three groups or types of areas as follows:

(1) The reserve within the areas of current development and production. It would be accounted for by such things as deeper producing formations, extensions to present fields, and the many favorable areas which come to light repeatedly with the drilling and exploration which is continuously going on in these active areas. It represents the bulk of the current discoveries as well as the most available of the undiscovered reserves of the future.

(2) A little less apparent, but certainly of greatest importance to the future, are those reserves which may be expected to be found in the partially explored regions fringing the areas of current development. They may be expected to be found in such regions as the trans-Mississippi embayment territory of Mississippi and Southern Alabama; the West Texas and trans-Pecos region of Texas and New Mexico; the Anadarko basin on western Oklahoma and adjacent parts of Texas, Colorado and Kansas; and the central and northern part of the San Joaquin Valley in California. Each of these regions is characterized by large area; thick sediments which are known to be oil bearing in neighboring regions; folding, faulting, tilting, and deformation on a large scale; local evidence of oil within the area; much geologic history favorable to oil accumulation; regional unconformities; overlaps, wedge belts of porosity, and lateral gradation on a large scale; and all are located where access to present markets does not present too much of a problem. In other words, the geology may be called big geology and the resultant discoveries may also be expected to be big from an industry or national viewpoint. Certainly, within any of these areas the eventual discovery of 25,000-50,000 or even 100,000 barrel wells is a strong possibility and the geology is of such a large scale that there is nothing in our present day concepts of the size of oil fields which in any way limits size of oil fields which may ultimately be found in areas such as these.

(3) The third group in this classification of possible future producing provinces are farther removed from current development and the character of the geology is not as well known as in those areas where more development and exploration has taken place in the past. This group consists of such areas as the many sedimentary basins in the Rocky Mountain region; the region of the Dakotas; the Salina-Forest City basin of Nebraska, Iowa, Kansas and Missouri; eastern Colorado; western Nebraska and eastern Wyoming; Florida and the neighboring states of Georgia and Alabama; and the upper Mississippi embayment region of Arkansas and Tennessee. Areas such as these comprise enormous potential producing provinces but their immediate importance is possibly not as great as the other two groups for the reason that they are generally farther from existent markets and marketing facilities; past exploration has been meagre with the result that less is known of operating conditions and they are therefore more hazardous; and new data develops more slowly because interest in the areas is less general and consequently there is less of the competitive urge to enter the area for intensive exploration.

(4) Still another major oil reserve within the United States is to be found in the enormous quantities of oil shales which occur in the Rocky Mountain region; in the vast coal resources;



Since supply yards such as the one pictured at the left will be greatly depleted, production drilling must perforce be limited but wildcat drilling will have to be encouraged to maintain known reserves.

particularly in the Rocky Mountain region also, from which petroleum products may be manufactured through hydrogenation and other methods; and finally in the various synthetic methods for the extraction of petroleum products from various waste products of farms and factories. This group is not considered further in the present discussion for the reason that their widespread use seems to be delayed indefinitely—certainly until some shortage occurs in the more readily available sources of crude petroleum which would tend to increase the costs appreciably above those prevailing at the present time.

Areas such as those in the first three groups above described are listed because they all fit in with our modern concepts of the occurrence of oil and gas—that is, they contain geologic conditions which geologists regard as favorable to the origin and accumulation of oil and gas. Briefly these are: (1) Thick sediments, chiefly marine, and unmetamorphosed. (2) Evidence of oil and gas. Such evidence is in the form of showings in wells, oil and gas seeps, producing fields in the adjacent areas of similar sedimentation, and solid bitumens. (3) Regional unconformities which are so often found to be associated, either directly or indirectly, with oil and gas fields; and (4) Regional wedge belts of porosity, since much of the production of the past is related in some manner with wedge belts of porosity, either as individual pools or as provinces. These four conditions might be called common denominators of most of the known oil provinces.

Outside the United States proper, but within the North American continent, there are many other possible producing provinces in which much geology favorable to the accumulation of petroleum is also developed on a large scale. The great plains region of western Canada; large areas in Alaska; the sedimentary basin of the Maritime Provinces of eastern Canada; and nearly all of the coastal belt of Mexico bordering the Gulf, are examples of such large scale unexplored regions characterized by big geology, much of which is certain to be translated ultimately into comparably large reserves in the future. If we add to these the vast possibilities of South America—possibilities which can be but faintly realized at present—we wind up with a total volume of favorable unexplored oil territory in the Western Hemisphere such as to stagger the imagination.

The immediate problem, and even the chief problem of the future, is not the question of whether or not there is oil to be discovered, but rather, how is this disocvery to be made under the current economy? What are some of the limiting factors in the problem? Can an adequate discovery rate be continued into the future? One fundamental factor in the problem of the occurrence of oil and gas, which should be understood, is that each oil field found so far is unlike every other known oil field—in other words, it possesses an individuality of its own. This is not to say that oil fields cannot be classified broadly into types, or that they do not have certain characteristics in common with each other, for they do. However, when we try to compare one field with another of apparently similar type, we find there are many differences in geologic history, time of folding, relation to lithologic and stratigraphic variations, age relations, relations to possible areas of accumulation, relatons to sedimentary basins, or in some other fundamental characteristic. Oil fields are found to occur through almost every conceivable combination of ages or rocks from Tertiary to Ordovician; of deformation, from simple to complex folds and faults to no apparent deformation; of time of deformation, from one period either early or late with relation to the reservoir rock time to several periods; of reservoir rock, from uniform, blanket sandstones to locally variable, lenticular, erratic mixtures of sand, lime and shale to limestones and dolomites of varying porosity; and to character of accumulation, from gas or oil through all combinations of gas, oil, distillate, and water under varying conditions of temperature and pressure. The word variable best describes the conditions under which oil and gas are found. This means that the next oil field to be discovered is different from anything else that we have ever seen in the past in at least one, but probably more, of its fundamental characteristics. Too often we have looked for another Oklahoma City, another Salt Creek, or another East Texas, when such a thing is an impossibility. Stated differently, it means that each commercial field represents a favorable coincidence of many elements, the absence of any one of which may well have meant no oil field.

Another factor which applies to most areas in the United States is that the new oil fields are found to be gradually getting deeper and deeper. In addition, the geology is becoming more and more complex for we are dealing progressively more with buried faulting, buried folds, buried unconformities and overlaps, and with unforeseen underground variations in lithology and stratigraphy. We probably unknowingly dealt with such phenomena in the earlier geological work but only now, with the great improvement in methods and techniques of obtaining accurate and detailed subsurface data, are we really becoming aware of their presence and significance. All of this means a steady increase in the cost of exploration, with no indications of any lessening in the future.

Oil discovery in the United States has been at a most satisfactory rate in the past. Probably the basic reason behind this achievement has been the opportunity and the incentive for profit if the venture proved successful. This has not only permitted, but has encouraged the drilling of countless test wells, which in turn gave direction to innumerable ideas, techniques, philosophies, and methods of attempting to reduce the risks inherent in the discovery process. These ideas ranged from the least scientific to the most scientific, with the more scientific methods gradually gaining the ascendency. The reasoning immediately back of the location of any wildcat test well is often exceedingly complex, combining varying factors of miscellaneous geologic

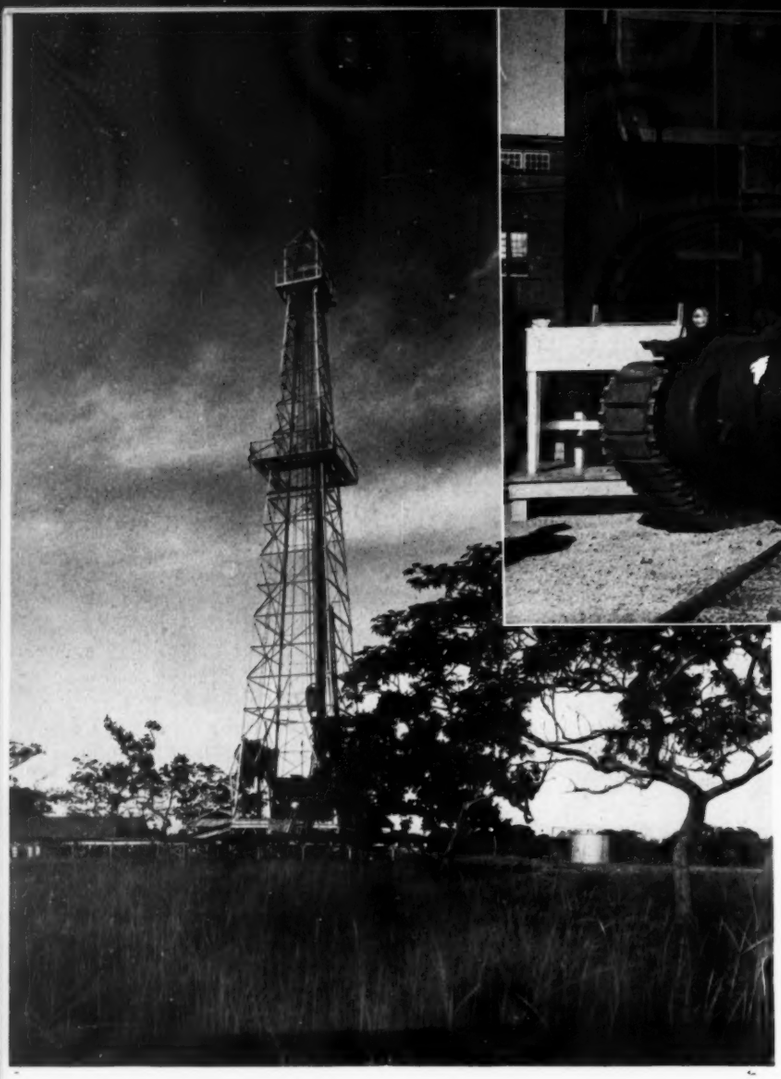
Wildcat as opposed to production drilling must be encouraged to add to known reserves from the great unknown reservoirs that may be assumed to exist undiscovered in various parts of the United States.

data, business and lease requirements, hopes for profit, and fears of loss. Because the problem of the occurrence of oil and gas is essentially a geological problem—that is, it is a problem of adjusting and correlating numerous geological variables into a logical explanation—its solution should be, and is, subject to scientific methods. The responsibility, therefore, for the thinking necessary to guide the discovery effort is being given the geologist in increasing amounts. The geologist—and by this is meant anyone who thinks in terms of the history and the relationships of the earth, whether he began as a geologist, a physicist, an engineer, a chemist, a mineralogist, or a paleontologist—typifies the scientific approach and offers the surest results for the lowest costs. He has at his disposal a wide variety of accurate data—geophysical, such as magnetic, gravity, electric, and seismic surveys; engineering, such as any one of a multitude of well surveys dependent on electric, radioactive, fluorescent, or other properties of the rocks; and also much accurate data concerning the conditions within the reservoir; geochemical, such as soil surveys, chemical well log surveys, acid treatment of reservoir rocks, and water analyses; and geologic, such as all kinds of surface and subsurface structural and stratigraphic maps, paleontological and micro-lithologic correlations, and paleogeographic and paleogeologic maps. As a matter of fact, he is being swamped with data to such a point that his data are often far ahead of his philosophy and of his ability to apply them fully. The opportunity has never been greater than now for the development of new theories, new philosophies, and new ideas which may be applied to the occurrence and to the discovery of oil and gas fields. The greater our reserve of discovery ideas, the greater the assurance that a sufficient number will continue to be translated into a satisfactory discovery rate in the future assuring maintenance of reserves.

The ever present urge for profits probably does more to liberalize our discovery thinking than any other one factor. It is closer to the independent and small operator than to the larger, complex organizations with the result that the independent operator drills most of the wells and for a number of years has been finding three out of every four new fields discovered. The major companies, with their large coordinated staffs of specialists, are more influenced in their attitudes by precedent by conservatism, and by past history, than is the independent with his greater daring, more liberal thinking, and greater use of intuition. Not that the small operator is not scientific, for he is, but he applies more flexibility to his interpretations, takes longer chances, and is not bound by too many facts of which the significance is not known. The lesson to be learned is that while discovery results from all methods that stimulate drilling, that the more liberally scientific the thinking, the greater the chances that more discoveries will be made. Many foreign countries in the Eastern as well as the Western Hemisphere have much unexplored geology which in the United States would be considered favorable to oil accumulation. With few exceptions, their discoveries have been negligible in comparison with their possibilities, probably due more than any other reason to the absence of the independent and the small operator. His absence is explained by the lack of incentive for him to take the risks of wildcatting and searching for new fields—in other words, the laws regarding land and property are against private ownership. Such exploration as is done is mainly by a few large organizations operating through government concessions and grants of land and drilling only where the most conservative and scientific of reasoning can be applied. There may well be dozens of major size oil fields in these countries but they will not be discovered until some method of drilling the required thousands of test wells is found. When it continues to take an average of 600 to 700 dry holes for each major oil field discovery in the United States, according to Wallace Pratt writing in the July, 1941 issue of Mining and Metallurgy, the value of much drilling in the discovery and development process becomes immediately and fully apparent.

The factor of increasing costs—which in effect generally means increasing profits—is in part being overcome by slim hole drilling, portable drilling and other similar techniques. This development in recent years is especially significant, for it kills two birds with one stone—first, it reduces drilling cost, and second, it thereby provides a method of drilling many test wells which would not otherwise be drilled. It is not only of great importance in production drilling, but in wildcatting it holds promise of being a geological tool of first magnitude for it gives the geologist an opportunity of obtaining data, which had heretofore been left solely to chance, and at a far less cost. It overcomes in a large measure the advantage which the independent or small operator had due to his more liberal interpretation of geological conditions and to his willingness to take longer chances and thereby drill discovery wells which would never otherwise have been drilled. Undoubtedly this type of drilling will be a dominant element in the discovery problem of the future for it is a field in which much intelligent and constructive work is being done.

The combination of a wide variety of reasoning together with the drilling of thousands of test wells annually continues to prove a powerful attack on discovery. It solves the question of the many variables within the problem of the occurrence of oil and gas. The question of the increasing costs is being met by less expensive drilling methods—slim hole drilling, portable rigs, and the like—which also permits the continued drilling of the many test wells necessary to discovery. Assured as we should be of the presence of vast quantities of undiscovered oil reserves, we can also be assured of adequate discovery if we preserve the basic factors back of discovery—the opportunities for individual initiative, for free enterprise and for profit. The more these factors are regulated, restricted, or submerged, the more the discovery process is jeopardized and in turn, the stability of the entire industry weakened insofar as it depends on reserves.



Which do we need most? General W. B. Pyron stated at the annual meeting of the American Petroleum Institute in San Francisco that a 136 ft. derrick requires about the same amount of steel as a medium tank. Photo on left by Robert Yarnall Richie, on right by Charles Phelps Cushing.

WARTIME PROBLEMS

Of The Petroleum Producing Industry

By Lester C. Uren

Professor of Petroleum Engineering
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CONDITIONS growing out of the war effort have created many problems with which the petroleum producing industry must contend. Military, naval and industrial demands for petroleum products have necessitated production of crude petroleum at unprecedented rate. Exploration for new reserves must be prosecuted actively and a vigorous drilling campaign to complete new wells as rapidly as possible will be necessary if we hope to maintain reserves at current levels. Field methods must be so planned as to assure maximum efficiency in conservation of oil and gas reserves and in utilization of equipment and material resources. Furthermore, these things must be done under increasingly difficult conditions, handicapped by a growing scarcity of essential materials and lower profits induced by increasing taxation, higher labor and material costs and a price ceiling that allows little or no advance in oil prices above peace-time levels.

Authoritative agencies have recently undertaken to formulate objectives for the field exploitation phase of the industry during the year 1942. Secretary Ickes, the Federal Petroleum Coordinator, has briefly stated in the Oil Weekly for December 15, what he hopes the industry will be able to accomplish in the following assignments:

(1) Produce at least 1,500,000,000 bbl. of crude petroleum if that quantity can be supplied without impairing the ability to sustain the necessary production during the emergency. (2) Drill a sufficient number of wells, efficiently spaced, to furnish that amount of oil next year and to prove up sufficient reserves to furnish at least that amount during the following year. (3) Operate all wells so as to conserve reservoir pressure to the end that the greatest practicable ultimate recovery will be attained at the lowest possible cost, with minimum expenditures required to provide artificial energy to effect production. (4) Conduct an exploration campaign that will result in the discovery of new supplies adequate to maintain a comfortable ratio between reserves and current annual consumption. (5) Maintain surface stocks of crude oil at adequate levels with respect to refinery requirements for the various grades and qualities of products, as well as stocks of the products sufficient to protect against any unusual demand that may arise.

There can be little difference of opinion among oil producers on the worthiness of these objectives. They can and will be achieved in some degree. One hundred percent realization of all of these objectives, however, will require intelligent understanding and control by regulatory agencies and the utmost cooperation and tolerance on the part of those engaged in the industry in conducting their operations in accord with the general plan. In the last analysis, the final result will depend very largely upon the efficiency, skill and cooperative spirit of the individual operators in every field. The efficiency of an industry is but the integrated result of the efficiencies of its individual components. It will be of interest to

consider briefly, some of the factors that have a bearing on each of these different objectives, and to develop a more complete picture of the problems confronting oil producers in planning their operations to accord with the program that has been thus set up for their guidance.

Secretary Ickes suggests that the industry must produce at least 1,500,000,000 bbl. of oil in 1942 to meet war-time demands. This is probably a conservative figure and actual production is likely to be greater unless civilian use of petroleum products is artificially curtailed. While restriction in the sale of new automobiles and automobile tires will unquestionably tend to reduce civilian consumption of motor gasoline—by as much as 35 percent, according to some authorities—it is believed that with large stocks of second-hand rubber that can be reclaimed and casings that can be retreaded for many thousands of miles of additional service, car owners will find it possible to keep in operation most of the 28,000,000 automobiles now on the roads in this country. Coastwise movement of oil is temporarily restricted by the hazards of sea transport and the need for tank ships in overseas military and naval service, but it is believed that local shortages of petroleum products occasioned by transport difficulties will not long endure. Largely off-setting these restrictive factors, is the likelihood of greatly increased demand for war-time needs. We are promised that American factories will turn out 60,000 planes in 1942, 125,000 in 1943; 45,000 tanks in 1942, 75,000 in 1943; American ship-yards will assemble 8,000,000 tons of shipping in 1942, 10,000,000 in 1943. Operation of all of these planes, tanks and ships will demand a sizeable contribution of crude from the American petroleum industry to produce the necessary fuel and lubricants with which to operate them. Accelerated war-time industries will also require a large and ever increasing contribution. One estimate, considered conservative in view of the recently greatly expanded war program, indicates that an all-out war effort would require an increase in crude production of from 13 to 19 percent over 1940 production, or from 180,000,000 to 265,000,000 bbl. This assumes that military, naval and civilian needs would be fully met. In addition to U. S. petroleum needs, the American petroleum industry will be called upon to supply increasing amounts of aviation gasoline, fuel oil and lubricants to our over-seas allies. Prospective requirements in this direction have been increased by the dislocation of the Netherlands Indies oil industry through Japanese military and naval operations. Increasing difficulty may be experienced in maintaining production from fields of Iraq, Iran and the Middle East.

United States production of petroleum reached an all-time high of about 1,400,000,000 bbl. in 1941, yet the minimum production estimated to be necessary for 1942 is in excess of this. In January, 1941, the average daily rate of crude production in the U. S. was 3,369,740 bbl. For January, 1942, the U. S. Bureau of Mines estimates that 4,138,400 bbl. were necessary. If the same increase occurs during 1942, we shall need about 4,900,000 bbl. per day in January, 1943; and if the average daily demand for 1942 is the mean between these two daily rates, the annual production for 1942 would have to be about 1,650,000,000 bbl.: An amount considerably in excess of Secretary Ickes' minimum estimate.

These figures assume that above-ground stocks of petroleum will not be increased or diminished. U. S. crude oil stocks have been declining since 1930 and of late the above-ground stocks have reached a critical level in the opinion of some authorities. Particularly is this trend a matter of concern when we measure the above-ground stocks in terms of days supply. Late in 1941, this figure had reached a low point of only 57 days supply. At no time during the war of 1914-1918 or during the intervening years since that time

Continuing General Pyron's comparison, one thousand feet of seven inch, 20 lb. casing would consume about the same amount of steel as ten 37-mm. anti-tank guns. The casing illustrated was manufactured by A. O. Smith and the anti-tank gun was photographed by Charles Phelps Cushing.

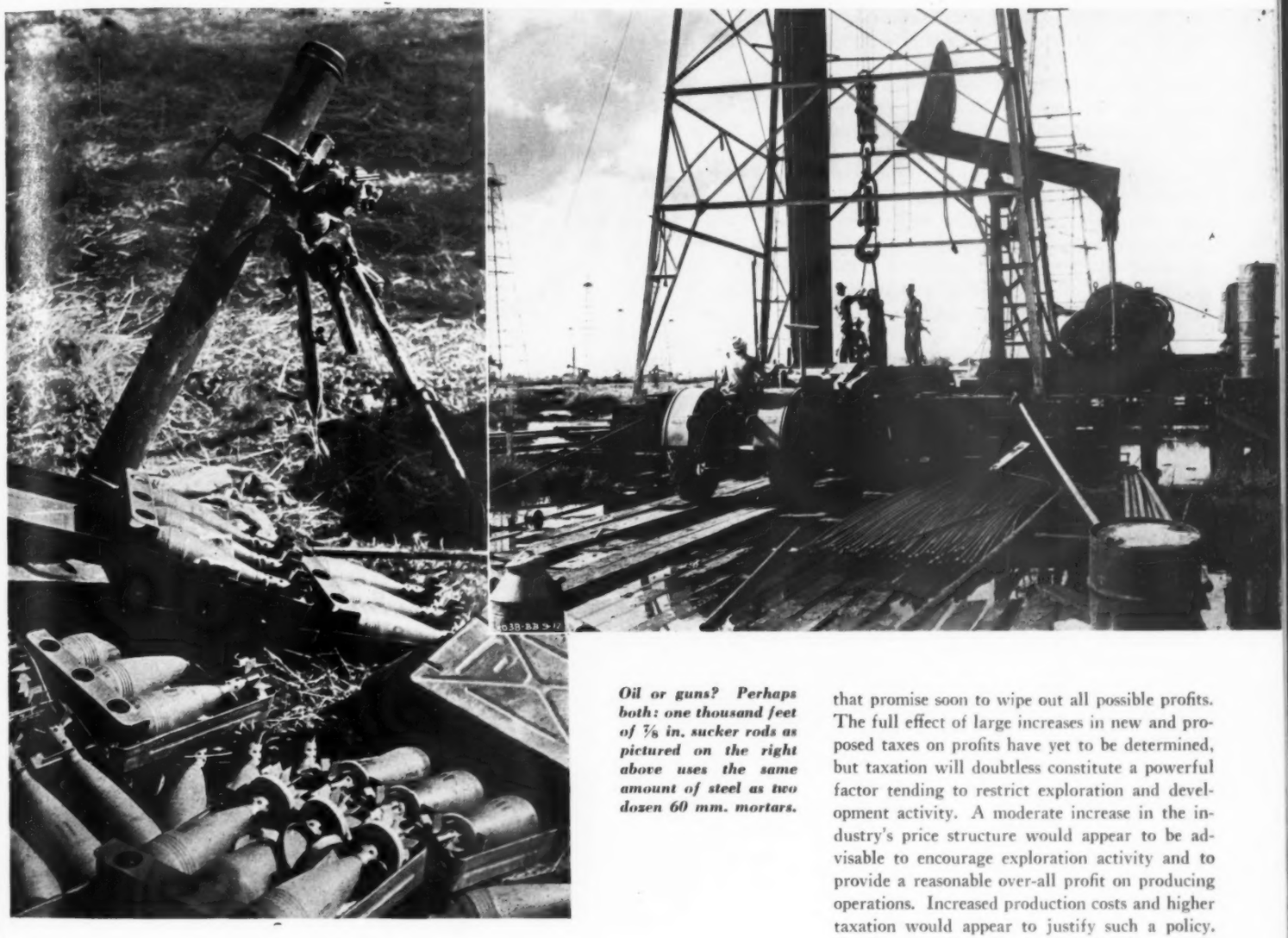
has the reserve been so low. Yet, during the last war it was thought necessary to restrict civilian use of gasoline. Col. E. O. Thompson, Chairman of the Texas Railroad Commission, believes that the demand for crude petroleum will increase to 5,000,000 bbl. per day during 1942, and that the production of the year should be sufficient to add 60,000,000 bbl. of crude and 50,000,000 bbl. of gasoline to above-ground stocks. Some authorities oppose increase in stocks because of the cost of the additional tankage necessary for its storage, especially at a time when use of steel is restricted, and because of the hazards of above-ground storage in time of war, particularly along sea coasts where most of our refineries and distributing facilities are situated.

Authorities could not be so complacent about the admittedly slender above-ground reserve, were it not for the idea, apparently firmly planted in the public mind, that we have immediately available a very substantial below-ground reserve of producible oil, obtainable merely by opening valves at well heads. The 20,000,000,000 bbl. reserve said to be available from present-known fields of the United States by flowing and pumping methods is, of course, not available at any rate of production that circumstances may require. There is a very definite upper limit to the rate of production that we may hope to maintain from this reserve, in the sense of a sustained rate of production over a period of years. Especially is this true if consideration be given to the loss in ultimate recovery that results from maintenance of a rate of production in excess of that dictated by the reservoir drainage conditions imposed by nature. It is true that in many flush fields wells are restricted in their out-put by back-pressuring, and that by removing such restrictions, a greater rate of production could be attained. However, this increased rate of flow would in most cases, be short-lived. The rate of flow would quickly decline, gas energy in the producing formation would rapidly be dissipated and inefficiently controlled edge-water would encroach irregularly and prematurely flood areas still otherwise capable of yielding producible oil. A greater rate of flow could be had for a few months, but it would not be sustained and we would ultimately produce less oil by taking it in this way than if flow were restricted. For every well there is a certain rate of production that is most efficient, that permits of utilizing the natural expulsive forces within the reservoir most effectively, and that results ultimately in production of the maximum amount of oil. Every well, every field should be operated at this, economically speaking, optimum rate. Detailed engineering studies of operating conditions will disclose this most efficient rate of production. It has been so determined in many fields, and considerations of conservation of petroleum resources demand that we do not allow the exigencies of the emergency to disturb it. More than this, in fields where the most economic rate of production is not now being realized—either because of competitive conditions or because operators have not taken the trouble or do not know how to determine it—steps should be taken at once to adjust production in these fields to the most efficient rate.

The daily rate of production that could be had from present-known fields of the United States without exceeding the economic optimum rate of production, has not been determined. Some authorities believe that it does not greatly exceed the present daily production rate. The writer has lately sought opinions on this matter from men in the industry qualified to express such an opinion and the resulting estimates have in most instances been between four and five million barrels per day. The current rate of production (January, 1942) is about 4,100,000 bbl. per day. Col. E. O. Thompson has stated that in his opinion, fields now producing in the United States cannot support a production of 5,000,000 bbl. per day over a long period of time without loss in ultimate recovery. In other words, it would appear to be the considered opinion of competent authorities that production much in excess of the present daily rate cannot be maintained economically from present reserves, and any additional supplies that may be needed should be provided by discoveries of new reserves. Apparently substantial increases in production are possible only in Texas and California, and even in these states only moderate increases are possible if the increased rates are based on consideration of conservation and maximum ultimate recovery of petroleum resources. Unfortunately, present methods of prorating production have been developed in many cases, with little or no regard for the most efficient production rates. Well potentials generally represent the open-flow capacities and when allowable rates of production are prorated on this basis, individual properties are often assigned allowable productions greater than they may efficiently maintain. In other cases it is possible that the assigned allowable production rates are lower than they should be for most efficient recovery, for in fields where expanding gas furnishes the expulsive energy, too low a rate of production may also result in loss of ultimate recovery. It is probable that the ultimate recovery obtainable from our remaining petroleum reserves could be materially increased if proper engineering studies were made of every producing property and the proration system revised so that all wells would be assigned allowable rates of production as nearly as possible in accord with their most efficient rates. Unfortunately a vast amount of engineering work would be necessary to determine these rates for every producing field and it is doubtful if the industry or the responsible proration agencies have at their command a sufficient reservoir of trained personnel and the necessary engineering equipment to undertake such a task and complete it within a short time. Furthermore, this survey would have to be a continuous process, each well being studied periodically, for the most efficient rate of production for a well is not a constant, but varies with reservoir and operating conditions. Difficult though it may be, yet it would constitute a notable contribution toward the conservation of our petroleum resources if such a survey could be made and our proration system, both during the war and afterward, changed to this new basis.

Of course, it must be realized that in dealing with a wasting resource producible by depletion of a reservoir of ever diminishing natural energy, production rates of individual wells must inevitably decline. Only by use of secondary recovery methods involving production under artifically developed energy, can we hope to maintain a constant rate of production from a given acreage. An exception to this statement must be noted in the case of water-drive fields where edge water enters the producing formation and maintains reservoir pressure as rapidly as the oil is withdrawn. In most fields where an economic rate of production is initiated, the rate of recovery must be expected to decline as production continues. A constant rate of production, utilizing primary expulsive forces, can be realized only by continually bringing new wells into production.

Flush production from these new wells may thus off-set the decline of older wells. Many do not appreciate the extent to which we are dependent upon the flush production of newly drilled wells in maintaining our current rate of petroleum production. The 21,000 new oil wells completed in 1940 had a gross initial production of 7,250,000 bbl. per day and contributed a large percentage of the gross potential capacity upon which proration schedules were based in 1941. We must continue to drill new wells in undrained, proven acreage to maintain production; and as proven acreage is quickly drilled, we must ever be exploring for new fields to provide additional sources of flush production. The need for new reserves to afford flush production to off-set declining yield from older fields and to provide additional oil to meet war-time demands, will necessitate an intensive exploration and wildcatting campaign during 1942 and for so long thereafter as war-time conditions may continue. Just how many new wells must be drilled and how many new fields must be found to meet these requirements will depend upon the efficiency of exploration methods, the percentage of dry holes, the yield of successful wells and the magnitude of the reserves discovered. Statistics indicate that the number of dry holes necessarily drilled in the finding of the average oil field has greatly increased during recent years and that the new reserves discovered per wildcat well drilled has greatly diminished, thus indicating increasing difficulty in finding new fields. Barring the development of new and more efficient exploration techniques, we should expect this trend to continue. We have only a definite number of accumulations of petroleum in this country and it is evident that as the more obvious of these have already been discovered, the remainder are likely to be more difficult to find. Also, they will be more costly, not only because a greater number of dry holes must be drilled but, being deeper, future wells will individually be more costly.



Oil or guns? Perhaps both: one thousand feet of ⅞ in. sucker rods as pictured on the right above uses the same amount of steel as two dozen 60 mm. mortars.

Estimates by competent authorities indicate that at least 30,000 new wells should be drilled in the United States during 1942. Probably more than this will be needed if we are to maintain reserves and provide sufficient flush production to meet prospective crude demand. The average well drilled in the United States during recent years has been about 3,000 ft. deep. Assuming that this average depth may conservatively be applied, it would appear that the total footage drilled during 1942 should be at least 90,000,000 ft. The average cost per foot of drilling has not recently been determined, but possibly averages about $7 or $8, including casing and fixed charges. The total expenditure of the industry for new drilling may therefore aggregate nearly $750,000,000 for the year 1942. Exploration activity cannot be expected to be responsive immediately to the need for additional production. In normal times, there is a lag of as much as three years between the creation of a favorable price structure and other factors that give impetus to exploration activity, and its consummation in the form of producible new reserves. While we may perhaps, expect some shortening of this period as a result of war-time demands, it is probably true that the exploration activity of 1942 will be determined largely by conditions that existed within the industry in 1940-41. The accelerated demand for oil that has suddenly developed during recent months, cannot be expected to have its full effect on the production and reserve situations until 1943 or even 1944.

In any analysis of the prospects for increased exploration and field development activity, it must be recognized that there are several adverse factors tending to retard the development program necessary to meet the situation now presented. The industry is now surrounded by a system of artificial controls that will probably largely prevent operation of the economic forces normally operative. Price ceilings already applied in some degree, promise to prevent increase in the petroleum industry's price structure that normally develops in response to a decline in the industry's reserves. At the same time, there is as yet, little or no control of rising labor and material costs and operators are being caught between the pincers of rising costs and stabilized selling prices that promise soon to wipe out all possible profits. The full effect of large increases in new and proposed taxes on profits have yet to be determined, but taxation will doubtless constitute a powerful factor tending to restrict exploration and development activity. A moderate increase in the industry's price structure would appear to be advisable to encourage exploration activity and to provide a reasonable over-all profit on producing operations. Increased production costs and higher taxation would appear to justify such a policy. Furthermore, higher prices permit of more efficient recovery operations, increasing the volume of economically recoverable oil reserves. Though the patriotic response of the industry might lead its more substantial elements to undertake needed exploration and development, even though possible profits seem negligible or actually insufficient to meet anticipated future production costs, there is doubt in the minds of many operators that the necessary materials will be made available. Secretary Ickes makes the interesting observation that each barrel of petroleum requires an expenditure of seven pounds of steel, and asks that some 5,400,000 tons of steel be made available for oil industry use during 1942. This is about six percent of the probable total production of steel within the United States during this year. In view of the probable need for abnormal amounts of steel for equipment and rehabilitation of many idle wells and that necessary for equipping the many thousands of new wells, it seems probable that this allottment may prove insufficient and that steel supplies to individual producers must be rationed. Indeed, the industry has been operating under a system of priorities for several months, not only in its purchases of

steel, but in the purchase of other essential commodities for drilling and production as well.

The prospective shortage of steel is one of the reasons for the 40-acre well spacing rule recently promulgated. Under restrictions imposed by O.P.M. Conservation Order M-68, as amended January 14, 1942, no operator is permitted to purchase or use new material in the drilling of a well unless it is the only well on the surrounding 40-acres. In restricting field development to a 40-acre well spacing program, the Petroleum Coordinator and his staff are venturing into a highly uncertain realm of petroleum technology. The area that may be drained efficiently by wells spaced in accordance with some recognized geometric pattern, is still a matter of controversy among authorities on oil-field development. There is one school that adheres to the theory that the amount of oil utlimately producible from a given field is independent of the well spacing; that fewer wells simply means a longer period of recovery. Others believe that lateral variation in the stratigraphic and lithologic characteristics of reservoir rocks and structural features of oil-bearing formations, create erratic drainage effects, and that wide spacing of wells means reduced ultimate recovery. Those adhering to the latter view-point contend that a 40-acre spacing pattern for wells will not secure efficient drainage, and such a spacing interval certainly would not be in accord with the industry's earlier practice. Nevertheless, it is true that 40-acre spacing of wells will result in minimum interference between wells, and that widely spaced wells will have better sustained yield and higher average initial productions than if a smaller interval were adopted. Where casing and other materials must be rationed, it is probably true that a greater quantity of oil can be produced per pound of steel or per dollar of development expense with widely spaced wells than with wells drilled within drainage influence of each other. However, it must be recognized that in fields where gas energy furnishes the expulsive force, we are in many cases probably sacrificing ultimate recovery for better sustained current yield by imposing the 40-acre spacing rule. Gas drainage of areas too remote from a well outlet to permit of efficient oil drainage, will result in diminished ultimate yield. Of course, undrained oil left in the reservoir rock by this practice is not lost and eventually can be recovered by application of secondary recovery methods. This however, must inevitably be higher cost production. It would appear likely that the Coordinator and his staff must be prepared to grant many exceptions to the 40-acre spacing rule. Conditions in different fields are so dissimilar that equitable application of any uniform interval between wells would be impossible. Spacing that might be considered appropriate for a thinly bedded "water-drive" reservoir should not be expected to apply to a multi-zone field with a great thickness of productive formation where gas energy is furnishing the expulsive force. If wells must be so widely spaced, it seems unlikely that the objective of 30,000 new wells during 1942 can be attained, for it would probably be difficult to find that many new locations worthy of test.

A determined effort is being made by government agencies to prevent increases in the price of crude petroleum and petroleum products. The Price Administrator has already denied requests for increase in crude prices submitted by oil producers in several regions. Recently completed legislation promises to make needed price adjustments more difficult during future months. Yet, it cannot be denied that present-day costs are materially higher than at the time the existing price schedules became effective. The trend is definitely toward higher cost levels, with little or no brake on rising labor, material, transportation and taxation costs being apparent. Indeed, the Government agencies would appear to have taken action in regulating prices with little direct knowledge of or regard for production costs. Not since 1934 has any agency of the Federal Government made a thorough study of crude petroleum production costs. While the Tariff Commission has lately taken steps toward assembling data for estimating recent production costs in each field and district, yet it will probably be several months before the results of this study can be made available. Furthermore, the situation is rapidly changing and cost data assembled in 1941 are not likely to be applicable to the conditions of 1942. A continuous study of the factors tending to influence the cost of producing petroleum would appear to be necessary, with the purpose of assembling timely data and formulating the cost factors in some way that would afford a basis for change in the petroleum industry price structure that will be necessary from time to time as cost factors undergo a change.

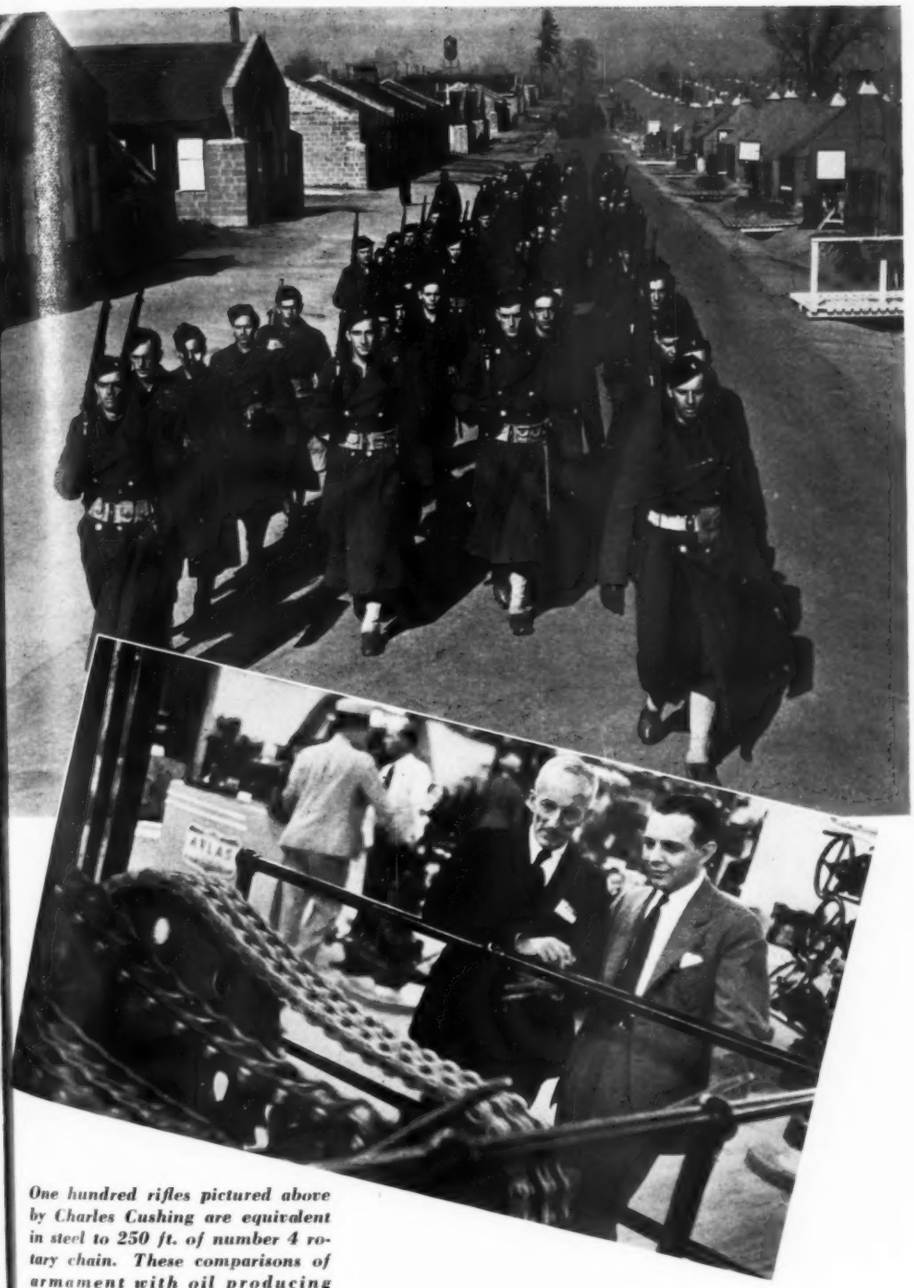
Rehabilitation of idle stripper wells is likely to be an important phase of the industry's war effort. During recent years, many small producers have been unable to compete economically with cheap flush production in prolific new fields. In some regions, entire fields have been idle. With the prospect of increased demand and provided higher prices prevail such wells and fields may again be operated profitably. In many instances, however, idle wells must be worked over and new pumping equipment provided before they can be placed on production. Many clean-out jobs will be necessary; redrilling and plugging operations will in some cases be required. Replacement of screens, liners, tubing, rods, pumps and pump parts and power connections must be made. Maintenance work of this character is often expensive and producers must be assured of suitable prices for their product over a period of time sufficient for redemption of the necessary capital. Because of the scarcity of steel and difficulty in purchasing new equipment, maintenance and repair work must be done with a minimum of new material. Previously used liners, screen pipe, tubing, rods, pumps and power appliances will be used wherever possible. Techniques that require a minimum of new material will be popular. For example, recent developments in the art of gravel-packing should permit of highly efficient screening without the necessity for purchasing new metal screens or screen pipe. Operators in some of the older fields have had long experience in utilization of second-hand equipment in meeting lease maintenance requirements. Fortunate operators who have been accustomed to ordering new material for every repair job would do well to take note of the practices in these older fields. Salvaging of line pipe from gathering lines no longer used, or casing from idle wells, will provide materials sufficiently dependable for many repair jobs. However, scarcity and high cost of new materials should not be permitted to encourage premature abandonment of small-capacity wells merely to provide casing for more profitable operations.

Conservation Order M-68 (amended Jan. 14, 1942) as recently promulgated by the Office of Production Management, restricts use of new material to cases in which not more than one pumping well is operated on each ten acres. Reasonably applicable throughout many Mid-Continent fields where 10-acre spacing of wells has been common, this provision will create great difficulty and confusion in other fields where closer spacing has been the rule. In certain California fields, for example, wells have been closely spaced because they produce from multi-zone reservoirs of unusual thickness. To shut in all but one well in each ten acres in such fields, where wells are already drilled and in operation, would result in many inequities and would lead to material reduction in current production. Unless it is planned to take care of such situations by reasonable exceptions, the conservation order would appear to be a misnomer in that it would likely lead to reduction in recovery efficiency, premature abandonment of wells and loss in ultimate recovery of valuable crude.

The threatening power shortage and the growing scarcity of conductor wire, motors, transformers and other electrical equipment, promise to place additional emphasis on internal combustion engine power. It would seem that plans for further electrification of oil industry operations would be inadvisable at this time.

For drilling purposes, the choice of prime movers should be limited to steam or internal combustion engines; while gas engines—in many cases perhaps, second-hand automotive engines—will be used for other oil-field purposes.

Ordinary present-day methods of producing oil by the natural expulsive forces, leave much of the oil immobile within the reservoir rock. Improved methods of secondary recovery involving application of artificially developed and applied energy afford means of securing an additional crop of oil. Estimates indicate that thousands of millions of barrels of recoverable oil are available in present known fields, producible by these improved secondary methods. Both gas-injection and water-



One hundred rifles pictured above by Charles Cushing are equivalent in steel to 250 ft. of number 4 rotary chain. These comparisons of armament with oil producing equipment give point to the problem of producing more oil with fewer tools.

flooding methods have been thoroughly tested and have been successful in many fields under a wide variety of conditions. Improved recoveries are also possible by special methods of drainage through mine openings. In time of oil scarcity and higher-than-normal prices, this reserve of petroleum producible by secondary methods, may be called upon to make up any deficit that may result from failure to find adequate supplies of flush production in newly discovered fields. Unfortunately, this reserve is not immediately available. Present prices are not high enough to justify wide-spread application of these methods. Very little new production could be secured by their application this year or next. Time is required to make the necessary engineering studies, drill and equip the additional wells that would be needed, install power and other surface equipment and begin to realize upon the expulsive stimulus resulting from restored formation pressure. Nevertheless, application of secondary methods in fields where conditions are definitely favorable, should be encouraged as a safeguard against the possibility that exploration will not be successful in finding new reserves necessary to produce the supply of petroleum that will be needed during the next few years. The Office for Production Management has recognized this need by placing no restrictions on the purchase of equipment for this purpose other than the general priority rules attaching to all oil-field equipment used in various producing operations. In recent months, many of the petroleum industry's younger men have been drawn into the armed forces. Some have been drafted, others have volunteered and many reserve officers have responded to calls for their services. Many men have been lured from oil industry positions to work in more remunerative jobs in various war industries. At the same time, the supply of young men entering the industry from schools and colleges has been greatly curtailed for the same reasons. With the prospect of further expansion of the armed services and war industries during the current year, it is likely that this trend will continue. Unless steps are taken to restrict this drain on personnel, we may presently find the petroleum industry without sufficient trained technologists to carry out the program of exploration, field development and production necessary to achieve the war objectives. Petroleum is as important a material in modern warfare as explosives or tanks or guns or planes or ships. The men who serve the petroleum industry are performing as important a service as men in the armed services or in any so called war industry. Means should be found to keep these trained men in the industry where they can be most useful. A man can be taught to fire a gun or drive a truck or a tank in a few months, but years of training are necessary to produce a petroleum engineer or geologist or chemist or skilled driller or production man. We can ill afford to lose the services of these men at a time when the industry is called upon to make its greatest effort. A still greater problem will be presented when the war ends and the many young men of the industry now in the armed forces return to claim the jobs that they left on entering the service of their country. These men have a greater claim on these jobs than those who have meanwhile taken their places. The many problems that will arise in converting the country from a war-time to a peace-time economy will probably come at a time of greatly diminished demand for petroleum products in industry. The return to peace may prove more difficult than was the preparation for war. If the industrial pattern of the post-war period of the early twenties is repeated, we should expect a severe depression in industry with a serious unemployment problem.

The petroleum industry cannot afford to lose the services of any of its trained workers by failure to offer them employment when this time comes. The industry has a large investment in these trained workers. They will be needed in its future development and plans should now be made to meet this situation when it develops. It may come earlier than now seems probable. The American Petroleum Institute and its member companies, or other responsible industrial agencies, should appoint a representative committee to study this problem and secure the cooperation of the oil companies in developing a post-war program designed to conserve the industry's trained personnel.

INCREASED WILDCATTING

Required to Maintain U. S. Reserves

By Frederic H. Lahee

More and Deeper Wildcat Wells Must be Drilled if Four Year Decline in Discovery Rate is to Be Arrested in Near Future.

IN THE present article we are bringing together, for comparison, some of the data already published on proved oil reserves and on wildcat drilling as indicated in the appended bibliography. Unfortunately, complete data are not available for more than a few years, and, with reference to wildcatting, we do not have satisfactory statistics on several states. Consequently, in order that a fair analysis may be made, we have limited this study mainly to the years 1937, 1938, 1939 and 1940, and to the combined states of California, New Mexico, Kansas, Oklahoma, Texas, Louisiana, Arkansas, Mississippi, Indiana, Illinois and Michigan. As may be seen by comparing certain items in Tables II and III with the data in Table I, these eleven states include a large proportion both of the proved oil reserves and of the wildcatting activities of the country. Figures for wildcatting accomplished and for reserves found in 1941 are not available at this writing. When published, they may be compared by the reader with statistics in the accompanying tables.

TABLE I

	Estimated proved reserves in U. S. at beginning of year*	Wildcats drilled during year indicated.* Number	Footage
1937	13,063,000,000 bbls.	2224	8,387,615′
1938	15,507,268,000 "	2638	8,860,484′
1939	17,348,146,000 "	2589	8,624,602′
1940	18,483,012,000 "	3038	10,144,870′
1941	19,024,515,000 "		

* These figures, for reserves, include the entire United States, but for wildcats they include all states regarded as prospective for oil except New York, Pennsylvania, eastern Ohio, West Virginia, and eastern Kentucky. In these states data were not available when needed.

The above figures on reserves are taken from "Facts and Figures", 7th ed., p. 74, published by the American Petroleum Institute, 1941. The data for wildcats were taken from the articles printed in the A.A.P.G. Bulletin, and listed in footnote, p. 57.

TABLE III

Statistics on Proved Reserves in Area Under Consideration*

	1937	1938	1939	1940	1941
	All figures in barrels (except G)				
A. Proved reserves as of Jan. 1 of year indicated	12,241,885,000	14,664,035,000	16,630,452,000	17,723,393,000	18,226,601,000
B. Net change in proved reserves since Jan. 1 of previous year		+2,422,150,000	+1,966,417,000	+1,092,941,000	+503,208,000
C. New proved reserves discovered during year indicated	896,692,000	805,293,000	337,989,000	280,882,000	
D. New reserves added through extensions and revisions of old fields during year indicated	2,739,254,000	2,313,356,000	1,955,507,000	1,505,816,000	
E. Total new proved reserves added (C+D)	3,635,946,000	3,118,649,000	2,293,496,000	1,786,698,000	
F. Production during year indicated	1,213,796,000	1,152,231,000	1,200,555,000	1,283,490,000	
G. Years of remaining proved supply on Jan. 1 of year indicated, based on production of preceding year	11.74 yrs.**	12.68 yrs.	14.43 yrs.	14.76 yrs.	14.20 yrs.
H. Newly discovered reserves (C) per wildcat hole drilled in year indicated	417,647	321,217	133,857	97,834	
I. Newly discovered reserves (C) per foot of wildcat hole drilled in year indicated	109.4	93.6	39.9	28.6	
J. New proved reserves (E) per wildcat hole drilled in year indicated	1,693,500	1,243,976	908,315	622,326	
K. New proved reserves (E) per foot of wildcat hole drilled in year indicated	443.88	362.52	271.36	182.07	

*This area includes California, New Mexico, Texas, Oklahoma, Kansas, Arkansas, Louisiana, Mississippi, Illinois, Indiana, and Michigan. Full statistics were not available on the other producing states.

**Production in 1936: 1,042,464,000 bbls.

TABLE II

Statistics on Wildcats in Area Under Consideration*

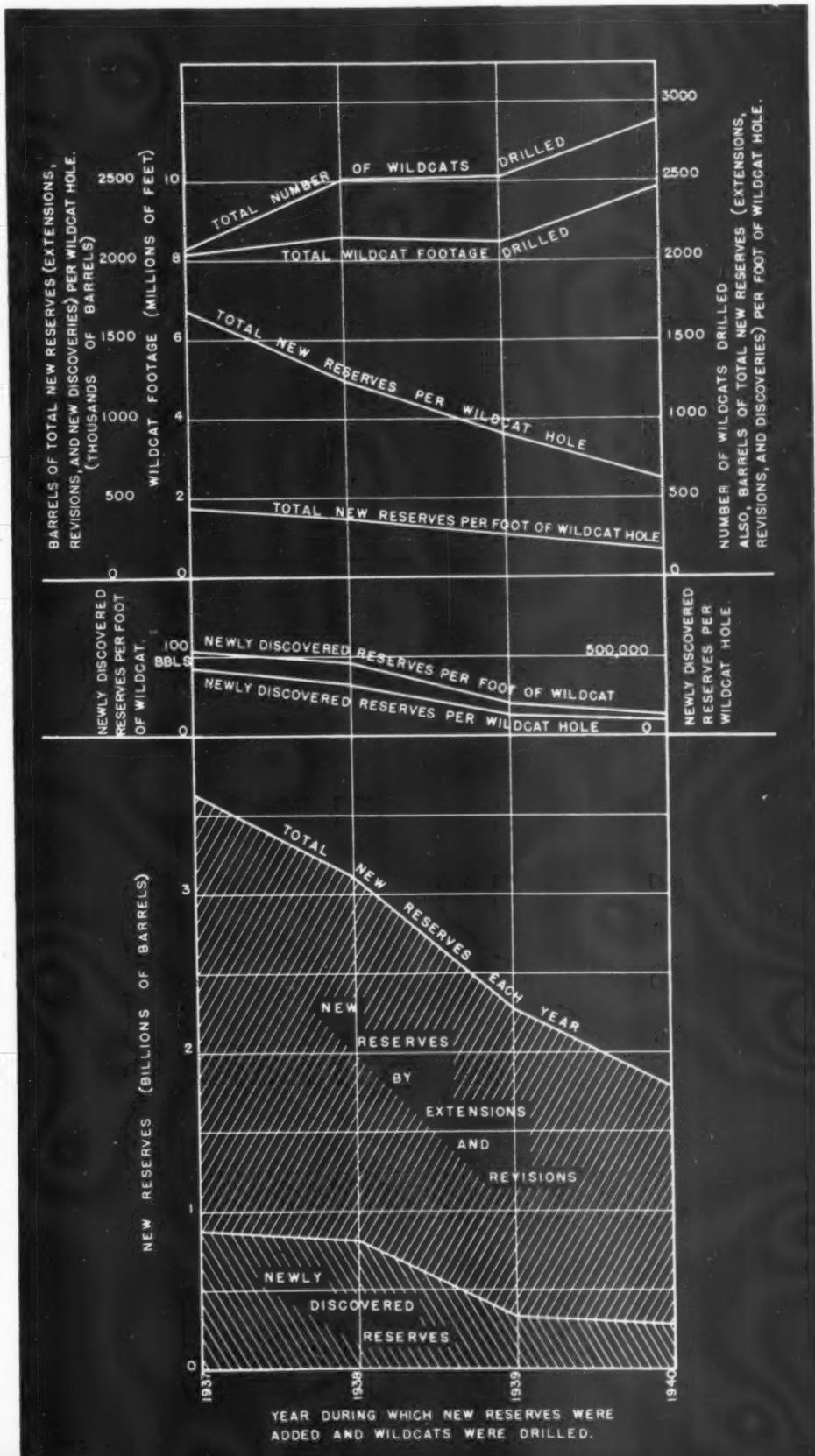
	Located on technical basis				Non-technical location				Unknown basis for location				Total				Grand totals # of wildcats	Total footage		Number of feet in dry holes drilled per foot in producing wildcats
	Producers		Dry holes		Producers		Dry holes		Producers		Dry holes		Producers		Dry holes			Producers	Dry wildcats	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%				
1937	214	16.05	1119	83.95	17	5.80	276	94.20	48	9.21	473	90.79	279	12.99	1868	87.01	2147	1,188,366	7,002,875	5.99
1938	283	17.93	1295	82.07	43	7.61	522	92.39	17	4.67	347	95.33	343	13.68	2164	86.32	2507	1,482,889	7,119,867	4.80
1939	216	13.33	1404	86.67	43	6.15	656	93.85	10	4.85	196	95.15	269	10.65	2256	89.35	2525	1,107,395	7,344,424	6.63
1940	309	15.69	1660	84.31	35	4.57	731	95.43	11	8.09	125	91.91	355	12.37	2516	87.63	2871	1,397,496	8,416,015	6.02
Total for '37-'40 incl.	1022	15.72	5478	84.28	138	5.94	2185	94.06	86	7.01	1141	92.99	1246	12.40	8804	87.60	10050	5,176,146	29,883,181	5.77

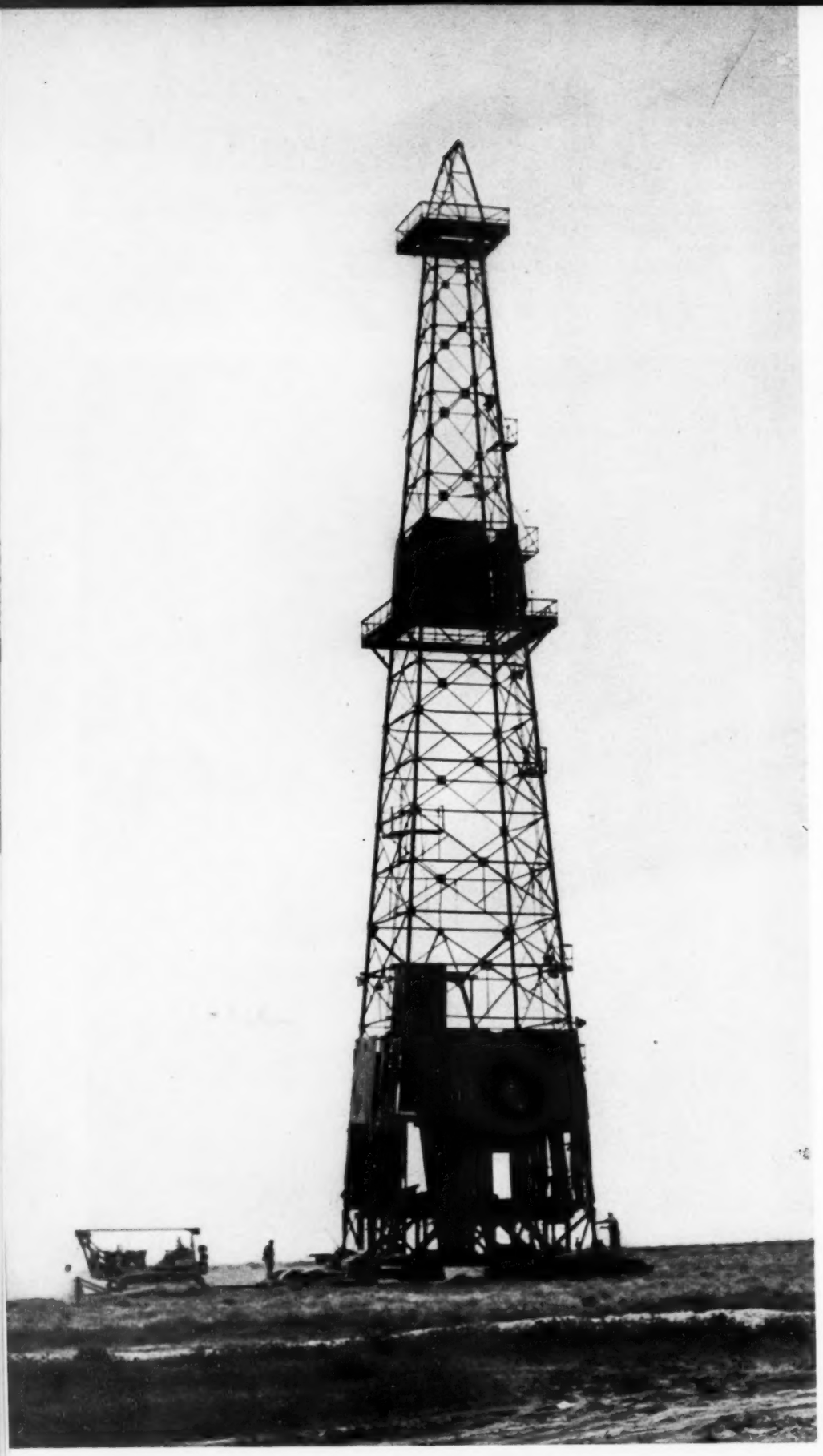
* This area includes California, New Mexico, Texas, Oklahoma, Kansas, Arkansas, Louisiana, Mississippi, Illinois, Indiana, and Michigan. Full statistics were not available on the other producing states.

For the purpose of this paper we are retaining the same definition for wildcat as that used in our earlier contributions printed in the Bulletin of the American Association of Petroleum Geologists. According to this definition, a wildcat is a hole drilled completely outside the known boundaries of pools already developed, and far enough from producing areas to be essentially a test of new possibilities. Generally speaking, such a hole would be at least two or three miles from production; but, where subsurface conditions may change within short distances, as in the case of lensing sands and salt-dome structures, or where the geology is complicated by faulting, and where, consequently, predictions based on the known may turn out to be greatly in error, a test hole may be regarded as a wildcat even if it is only one-half or three-quarters of a mile from production or from an abandoned dry hole. It is important to note that this does not make distance from a pool the sole factor in the definition; nor should it be. Often a hole to be drilled within less than a mile from production is just as much a wildcat, is just as much a financial risk, and should receive just as much encouragement in the search for new reserves, as a hole two or three miles from production. In every case the degree of uncertainty of the geological conditions should be taken into consideration.

As we have previously pointed out in the Bull. Am. Assoc. Petr. Geols., Vol. 25, pp. 164-166, 1941, there are two distinctly different methods of estimating oil reserves where drilling has shown that oil is present. In one case, as soon as oil is discovered on a structure, the estimated ultimate yield per acre is multiplied into the area which the geologist or engineer thinks the pool will occupy when fully developed, and this figure is assigned as new reserves to the new discovery well. In the second case a relatively few acres—say 40, or 160, or 640, perhaps, depending on several factors—are multiplied by the estimated per-acre yield, and the product is called newly discovered proved reserves; and, as more area is added to the pool through future developments, new increments in proved reserves are added as extensions each year until eventually perhaps as much oil may be found in the pool as would have been guessed at by the first method. The second method is not only conservative, but also it is subject to less error than the first method. In general we believe the second method is to be preferred. It is the method which has been consistently used by the American Petroleum Institute in preparing its estimates of proved reserves, some of the figures for which are quoted in Tables I, II and III.

Table I requires no special comment. Table II lists statistics on wildcat drilling in the area of the eleven states mentioned. These wildcats have been classified according to the reason for locating them where they were drilled, and also according to whether they were completed as producers of oil or gas, or were abandoned as dry holes. There is no need to repeat details of the table. However, we may call attention to the totals. In the four-year period, 15.72 percent of the wildcats located on a technical basis (geology or geophysics or both) were producers; 5.94 percent of the wildcats located on the basis of various non-technical reasons were producers; i.e., where the reason for the location was known, in collecting the statistics, those wildcats located on a technical basis were more than 2.6 times as successful as those located without technical advice. During this four-year period, 5.77 ft. of dry hole were drilled for every foot drilled in the producer wildcats. There are several ways of estimating the degree of success of wildcat drilling. In Table I, and in the summary statement above, we have called successful those wildcat holes (and the footage drilled in these holes), which were completed as commercial producers. However, we can consider wildcatting in relation to oil reserves discovered by this class of drilling.


BARRELS OF TOTAL NEW RESERVES (EXTENSIONS, REVISIONS, AND NEW DISCOVERIES) PER WILDCAT HOLE. (THOUSANDS OF BARRELS)
WILDCAT FOOTAGE (MILLIONS OF FEET)
NUMBER OF WILDCATS DRILLED ALSO, BARRELS OF TOTAL NEW RESERVES (EXTENSIONS, REVISIONS, AND DISCOVERIES) PER FOOT OF WILDCAT HOLE.
TOTAL NUMBER OF WILDCATS DRILLED
TOTAL WILDCAT FOOTAGE DRILLED
TOTAL NEW RESERVES PER WILDCAT HOLE
TOTAL NEW RESERVES PER FOOT OF WILDCAT HOLE
NEWLY DISCOVERED RESERVES PER FOOT OF WILDCAT.
NEWLY DISCOVERED RESERVES PER WILDCAT HOLE
NEWLY DISCOVERED RESERVES PER FOOT OF WILDCAT
NEWLY DISCOVERED RESERVES PER WILDCAT HOLE
NEW RESERVES (BILLIONS OF BARRELS)
TOTAL NEW RESERVES EACH YEAR
NEW RESERVES BY EXTENSIONS AND REVISIONS
NEWLY DISCOVERED RESERVES
1937
1938
1939
1940
YEAR DURING WHICH NEW RESERVES WERE ADDED AND WILDCATS WERE DRILLED.



Rig used in the discovery well at the Rasin City field in the San Joaquin Valley of California being skidded to a second location. Importance of this 1941 Shell discovery was the opening up of broad territory north of Coalinga for exploration which may prove significant in the future.

In Table III, under 'A', are recorded the proved reserves as of January 1 in each of the indicated years, and for the eleven-states area under discussion. Under 'B' is shown, for each January first, the net change in estimated proved reserves since the preceding January first, allowing for production during that twelve-months period. Under 'C' are the new reserves which are directly attributable to wildcat discoveries made during the year. Under 'D' are the revisions and additions of estimated reserves in fields already discovered in previous years, these revisions and additions having been made on the basis of new information obtained through development during the year indicated. Properly speaking, the reserves in group 'D' might well be assigned back to the year of discovery, but due to the present incompleteness of available statistics, this cannot be done. Instead, we may regard both groups of new reserves ('C' and 'D') as directly and indirectly resulting from original wildcat discoveries. If, for each year, we divide the newly discovered reserves ('C', Table III) by the number of wildcats drilled in that year, or by the total wildcat footage drilled in that year, we shall have a measure of the degree of success of wildcatting in terms of newly discovered reserves ('H' and 'I', Table III); and if we divide the total new reserves (discoveries plus revisions plus extensions: 'E', Table III) by the number of wildcats drilled, or by the total wildcat footage drilled, we shall have a measure of the degree of success of wildcatting assisted by outpost drilling ('J' and 'K', Table III). Under 'H' and 'I' the measure is short. Under 'J' and 'K', the measure may be too large or too small depending on how much should appropriately be assigned back to earlier years when actual discovery was made. In any case, then, there is an unavoidable error in estimating rate of discovery, or degree of success in wildcatting, measured in terms of new reserves; but the figures obtainable by these methods, as above described, are a significant index. They reveal a regular drop in rate of discovery through the four-year period, whichever way we compare the data. (See Fig. I.)

What is the significance of this falling rate of discovery? It cannot be due to lessened activity in wildcatting, for, except for a temporary setback in 1939, the number and average depth of wildcats has increased through the four-year period. Nor can it be due to any lessened application of technical methods in exploration, for there has been a steady advance in the refinement and use of techniques. We believe it is due mainly to the growing difficulty of finding new geological traps for oil. The more conspicuous and easily mapped structures have long ago been located and drilled. Also, drilling has tested most of the shallower prospects on these structures. Remaining undiscovered reserves are largely either (1) in regions not yet explored; or (2) they are in reservoirs deeper than those reached on already exploited structures and often unconformably related to the strata that contain the known reserves; or (3) they are in reservoirs of

Left, developments such as this one in Ventura County, California require extensive development as is indicated by the International Harvester Diesel engaged in road construction; scarcity of materials and time may limit such development work for the immediate future. Below, operators have shown a marked preference for mechanical rigs in recent years.

the stratigraphic pinch-out type, which can seldom be located by surface observations.

To look for oil under the first of these conditions will need increased activity in exploration and in drilling in areas which do not now produce oil, but which are rated as having some prospects. To look for oil under the second of the conditions just mentioned will require deep wildcatting and also deeper drilling on known structures or within the confines of known pools. To look for oil under the third condition will require the drilling of many holes, some of which may be purely informational, but all of which will help in locating the positions and trends of subsurface stratigraphic pinch-outs. If we are to maintain a satisfactory discovery rate, as applied to new reserves, we must become more vigorous than heretofore in our wildcatting campaign. We must show a strongly rising curve in the annual number and in the annual average depth of wildcat operations.

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HOW MAY DECLINE

N DISCOVERY RATE BE CHECKED?

By Joseph L. Adler
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A GREAT DEAL has been written in the last few years about the decrease in the rate of discovery of new oil reserves. Various suggestions have been made as to how we may hope to reverse the direction of this descending curve. But the curve has continued to descend. Possibly the proponents of the diverse methods which have been offered as solutions of this problem can claim with some justification that their suggestions have not yet been applied with sufficient intensity. It is difficult, however, to compel the investment of any considerable amount of capital in methods which are still considered experimental by the oil industry. All of the suggestions for increasing the rate of discovery which have come to the writer's attention are still generally classified as experimental by the petroleum industry.

Most of what has been published in this vein recently resolves itself into the recommendation of one of three forms of attack. Preeminent in recently published articles on the subject is the proposal of large-scale geochemical surveys. The proponents are, of course, principally the geochemists, and in their untiring efforts to educate the oil industry in the new exploration method which they are developing, they doubtless are accomplishing a valuable service. The opponents of such large-scale application of the new technique are that large majority of the oil exploration industry who are not yet convinced that geochemical surveys have demonstrated a degree of infallibility which would justify appropriations for their use to a degree that would reduce the funds available for methods of proved worth. At a time like the present when the urge for exploration has seized upon the oil industry with great force, any method of prospecting which holds forth promise is in danger of inspiring excessive faith. Such excesses inevitably react in the end to the detriment of both the oil industry and of the method itself. It is fortunate therefore, and rather surprising, that the able advocates of geochemical surveys have not yet received disproportionate support.

Another line of attack recommended and practiced by many prominent geologists is prospecting for stratigraphic traps. It cannot be denied that a number of the known stratigraphic traps contain large reserves of petroleum. It is a rather strange coincidence that only a relatively small proportion of the larger stratigraphic traps so far discovered are located in the United States. On the whole, little attention is today called to the fact that a tremendous number of stratigraphic traps have been discovered in this country during the past eighty years, but that most of them have been, individually at least, insignificant with respect to their contribution to the oil reserves. Actually the differentiation between stratigraphic traps and so-called structural traps involves some rather fine distinctions. Even in the larger and more definitely stratigraphic traps the distribution of oil, gas and water is controlled by structural details such as anticlinal noses, faults and structural terraces; water nearly always occurs in the structurally lowest portions of the general area of the fields, even though the corollary statement that the oil and gas occur in the structurally highest portions of the area is not so generally true. Also, in a great proportion of the fields which are commonly classified as structural traps, lateral variations in stratigraphy play a large part in the distribution of oil, gas and water, and in many of them where the oil occurs entirely on the flanks of closed anticlinal structures, the closure is scarcely more than incidental, and the trap is in fact chiefly stratigraphic in the usual sense of that term.

These considerations make it essential to have available all the structural information possible in prospecting for stratigraphic traps. Yet a great many wildcat tests are drilled at random locations along certain trends, where it is believed that particular known reservoir sands may be expected to pinch out producing stratigraphic traps, without any attempt to determine first the details of the local structural conditions. It is obvious that such test holes may easily miss the discovery of a stratigraphic accumulation of oil by only a few hundred feet of error in location, due to the accidental selection of a structurally low drilling site. The factors determining the location of such ill advised tests are usually matters of convenience such as the availability of large blocks of acreage at little cost, out of which a wildcatter can sell spreads at low prices to defray the expense of a well, or the discharge of a drilling obligation on a block which through neglect or other circumstance had not been properly investigated by geophysical or other geological methods before the obligation came due. Such wells, masquerading as stratigraphic tests, constitute a large proportion of the prospecting for this type of petroleum reservoir. Many a marginal geophysical prospect rejected for lack of sufficient indicated closure would make a far better location for a stratigraphic test. Can these random tests add considerably to our petroleum reserves? History shows that the answer is obviously: "Eventually, yes." Eventually, another East Texas type of oil field may be discovered in this way. But at a time when the exigencies of national defense require the immediate increase of our petroleum reserves to meet any unforeseeable demand which this unpredictable war may bring upon us, a more systematic and more scientific application of the valuable drilling materials used in drilling wildcat tests will more surely bring the urgently needed results.

The third form of attack now often recommended for increasing the discovery rate is, in the writer's opinion, the most radical. Several authors, notably geophysicists, have pointed out during recent years that the initiation of epochs of great petroleum discovery has coincided with the introduction of new methods of exploration. From this apparent relationship they draw the conclusion that what is now needed is a new exploration method. There is some tendency for them to overlook the fact that the initiation of discovery periods coincides even more closely with periods of good market demand and fair crude oil prices. In fact, most of the successive new methods of exploration were introduced several years before the series of discoveries attributed to them became evident. The new methods were not and could not be undertaken on a large enough scale to produce noticeable results except at such times as the profit from the oil industry was sufficient to finance them and demand their application on a wide scale.

The dictum, therefore, that the exploration branch of the producing industry turn its attention from the search for oil fields to research for new methods of exploration is not so clearly indicated by the finger of history as the advocates of this course believe they have demonstrated. With the increased demand for petroleum which the national defense has created the natural laws governing production and exploration will quickly increase the discovery of new reserves provided a fair price is fixed for the product. The history of petroleum exploration teaches us this, just as surely as it teaches that discoveries follow the introduction of new methods. It would therefore be deleterious to the national welfare in the present emergency to make any move that would encourage the transferring of men and equipment now engaged in petroleum exploration into the more speculative field of pure research. It would be foolish to imply that such a diversion of scientific effort might not produce a new method of petroleum finding that would result in numerous oil field discoveries. Such a result is definitely within the realm of possibility. But like the discovery of stratigraphic traps by random drilling, it is merely an eventual possibility. Methods already available are capable of producing immediate results, as is clearly demonstrated by the

Photo by Robert Yarnall Richie for Geophysical Service, Inc.

Because of the stigma attaching to a geophysicist's recommendation of a location that proves unproductive when tested by the drill, there is a tendency to file without testing all but the very best geophysical prospects. Many of these might yield excellent results if they were now disinterred and reexamined. Photo by Robert Yarnall Richie for Geophysical Service Inc.

numerous oil field discoveries which are still being made by the use of the five outstanding methods of pre-discovery exploration today, namely; surface geology, subsurface geology based on deep well logs, core drilling, gravimeter surveys and reflection seismograph surveys.

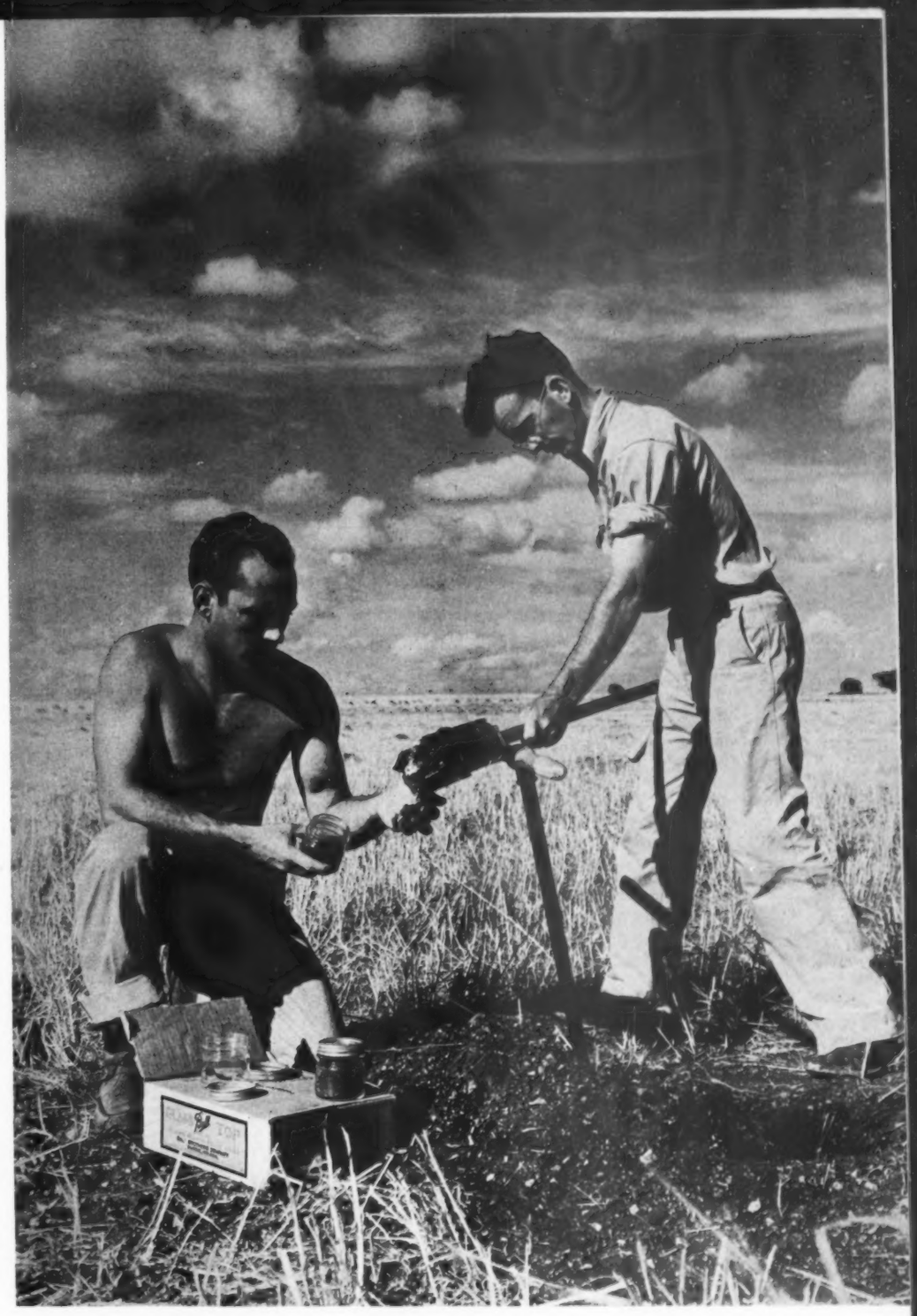
Yet the writer would not, at this particular time, recommend the increased application of these accepted geological and geophysical methods beyond the point of activity which they have reached in the first quarter of 1942. An increase in the application of the methods cannot be as productive of immediate results as the drilling of the numerous untested or insufficiently tested prospects which have been located during the last decade of geological and geophysical exploration. It is safe to say that there is no oil company with an active geological or exploration department that does not have in its files a large number of partially or imperfectly outlined prospects which either have never been drilled or have not been drilled deep enough. In some cases even where the prospect has been drilled to a sufficient depth, a careful study of the log of the dry hole will reveal that unusual stratigraphic or structural conditions, such as a local shaly condition in the objective sand or a possible fault cut by the drill, render that particular hole valueless as a test of the structure. It is even safe to say with assurance that in the offices of some oil companies where there have been numerous changes in personnel during the last ten years, many encouraging prospects now lie in the files forgotten. A layman, or even an oil man not directly connected with the exploration branch of the industry, might be inclined to doubt such a statement. Being familiar with the vast sums of money expended on geological and, more particularly, on geophysical work, he would seriously question whether any prospects thus pigeonholed could have any real merit. But to any geologist or geophysicist active in petroleum exploration, the existence of an astonishing number of such prospects is well-known. The pigeonholing of so many untested prospects is the result of an attitude. And an increase in the discovery rate can most quickly be effected by a change in attitude. Its development is directly attributable to the economic depression of the thirties. When petroleum reserves were large and demand was low, a geologist was not condemned because his years of effort added little oil to his employer's already ample reserves. But he quickly incurred sharp criticism if his recommendations resulted in a dry hole, the cost of which had to be paid out of the company's meager profits.

The situation with respect to reserves and demand has been undergoing a change during the past few years. The attitude, however, has persisted. When a prospect is submitted to the geological department of an oil company, more often than not all attention is given to examining it for defects. It is rare to see the attitude taken that, admitting the prospect to be imperfect, it is the part of the geologist at least to weigh the merits of the prospect against its shortcomings. Since every wildcat prospect is inherently fraught with risk, and experience shows that at least the first well drilled on the great majority of them is a dry hole, it is only by looking for its good points that a geologist may hope to sell himself on ever drilling, or supporting the drilling of any prospect. Too often the discussion of a prospect resembles a trial in which a geophysicist or a representative of the land department or a promoter appears in the role of the prospect's advocate and the geologist is at once the prosecutor and the judge. It falls to the advocate to present the merits of the prospect while the geologist who is much better qualified to seek out these merits as well as the defects gives little attention to the former except in so far as they are called to his attention by a person less qualified to see them. Is it any wonder that many a prospect is drilled on which nobody concerned has any real geological information whatever, simply because lacking such information, there is no basis on which the geologist can condemn it? Faced with such a proposition, if the play is cheap enough, the geologist can and often does concede that he has no objection to drilling being undertaken in a given location as a stratigraphic test, and as nobody really expects a stratigraphic test to produce anyway, he thus avoids the stigma of having the recommandation of a bad location charged against him. Another result of this attitude is that at times a great excess of geophysical exploration is done. Rarely confident that the prospects which his geophysical campaign has turned up are good enough for him to recommend drilling, the geologist in charge will go on and on with the exploration as long as funds are available in the hope of turning up something better. When the funds are finally cut off he may have to select something to drill to justify

the expense he has incurred, but many a prospect nearly as good as the ones selected for testing with the drill are put on the shelf and therefore implicitly tagged "rejected." In consequence of this practice geophysical exploration has long endured a "feast or famine" status. When the tests have been drilled, whether they are successful or not, the management senses that expenditures for geophysical exploration have been excessive, and that type of prospecting then remains suspended or considerably curtailed until the failure of other methods compels the resumption of a search for geophysical prospects. When the search is resumed, instead of resurrecting some of the prospects previously passed over, because of the stigma attaching to them through the implied rejection, the geological department leaves them untouched in the files while a new geophysical campaign is started in quest of newer and better prospects. During the last three years some of the major oil companies have relieved their own geophysical departments of the burden of this fluctuating load by reducing their geophysical staffs, and using the geophysical contractors to supply their peak demands. This does not, however, relieve the burden on the profession as a whole. How much more efficient geophysical exploration could be if it were maintained at a moderate pace such that exploratory drilling could keep up with it, is self-evident.

With the stimulus given to wildcat drilling last year by the orders of the O.P.M. providing prior delivery of drilling materials to wildcat wells, the present relationship between geophysical exploration and wildcat drilling appears to be well-balanced. If the habit of following up all reasonable geophysical and geological leads with wildcat tests can become reestablished in the minds of petroleum geologists, the discovery rate will certainly be increased. Obviously, the number of dry-holes will also be increased, but not in as great a proportion. For with the increase of drilling on geological prospects, the proportion of drilling based on non-geological considerations will perforce be reduced.

It was pointed out earlier that the war in which we are now engaged is unpredictable. At present no question is raised as to the sufficiency of our oil production in meeting the needs of defense. Defense, however, is only a preliminary step. We all know that the war can eventually be won only by aggressive action, but do we realize completely the scale on which this aggressive warfare will have to be waged? It is well within the bounds of probability that the war demand for oil production, at least for oil production in certain parts of the country, will at some future time require the drilling of so many development wells that wildcatting will have to be curtailed rather than encouraged. Materials may not be available to test some of the geophysical and geological prospects which are now, knowingly or through unwitting neglect, being held in reserve. For this reason the service of the nation requires that wildcat drilling not only keep pace with geological and geophysical exploration, but that it catch up with it. At present there does not lie within the grasp of the Axis countries any such vast store of untested geophysical and geological oil prospects as we know exist within the domain of the United Nations, but a great many known but undeveloped prospects do lie well within the reach of Axis thrusts. If we test our own prospects now while time and men and material are still available for the purpose, our ever amplified supply of oil may be the deciding factor in the winning of the war.



Since there is no certainty, even in the best geophysical prospects, until they have been tested by drilling, there is a second tendency on the part of the geological and geophysical departments to extend their preliminary exploration work as long as funds are available, passing over some excellent prospects in the hope of finding even better indications of structure. This tendency also leads to the accumulation of filed prospects that are only slightly if at all inferior to locations on which successful tests have subsequently been drilled. Photo by Robert Yarnall Richie for Geophysical Service, Inc.

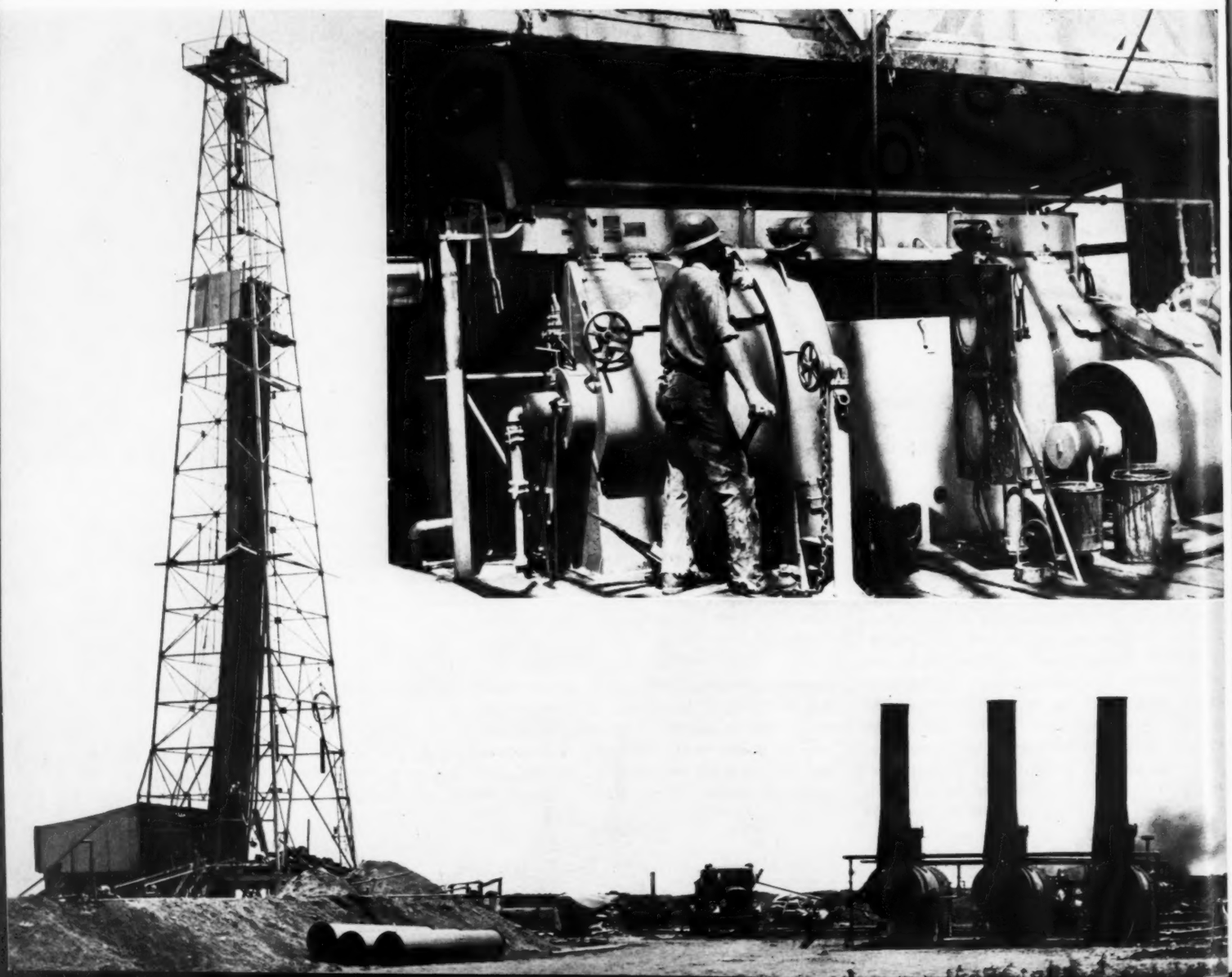
LESS STEEL—
MORE OIL

Is Problem of U. S. Drilling Contractors

Drilling Contractors Face Difficult Problem in Maintaining Their Organizations for Anticipated Future Demands While Confronted with Drastic Limitations.

THE drilling of oil and gas wells at this time is primarily a manufacturing process that assures the country adequate petroleum reserves for any national emergency. In this instance, producing wells are literally created or manufactured, just as factories for turning out armament and necessary supplies are created. The need for continuation of necessary oil development closely parallels the necessity for manufacture of lumber, steel, cotton and wool yardage, and leather goods. While it is true that present developed oil reserves might meet all demands for some time, the United States cannot afford to permit the actual demand for petroleum products to approach the maximum safe production rate. If the war proves to be a long one, our present developed oil reserves may be inadequate. Both the Petroleum Coordinator and the oil industry agree that continuation of drilling activity is essential to maintenance of satisfactory oil reserves. Over-production of oil since the last World War was not justified, but if heavy drilling campaigns in major producing areas have done nothing more, they have given us a dependable supply of inexpensive petroleum products when we need it most. Realization that the

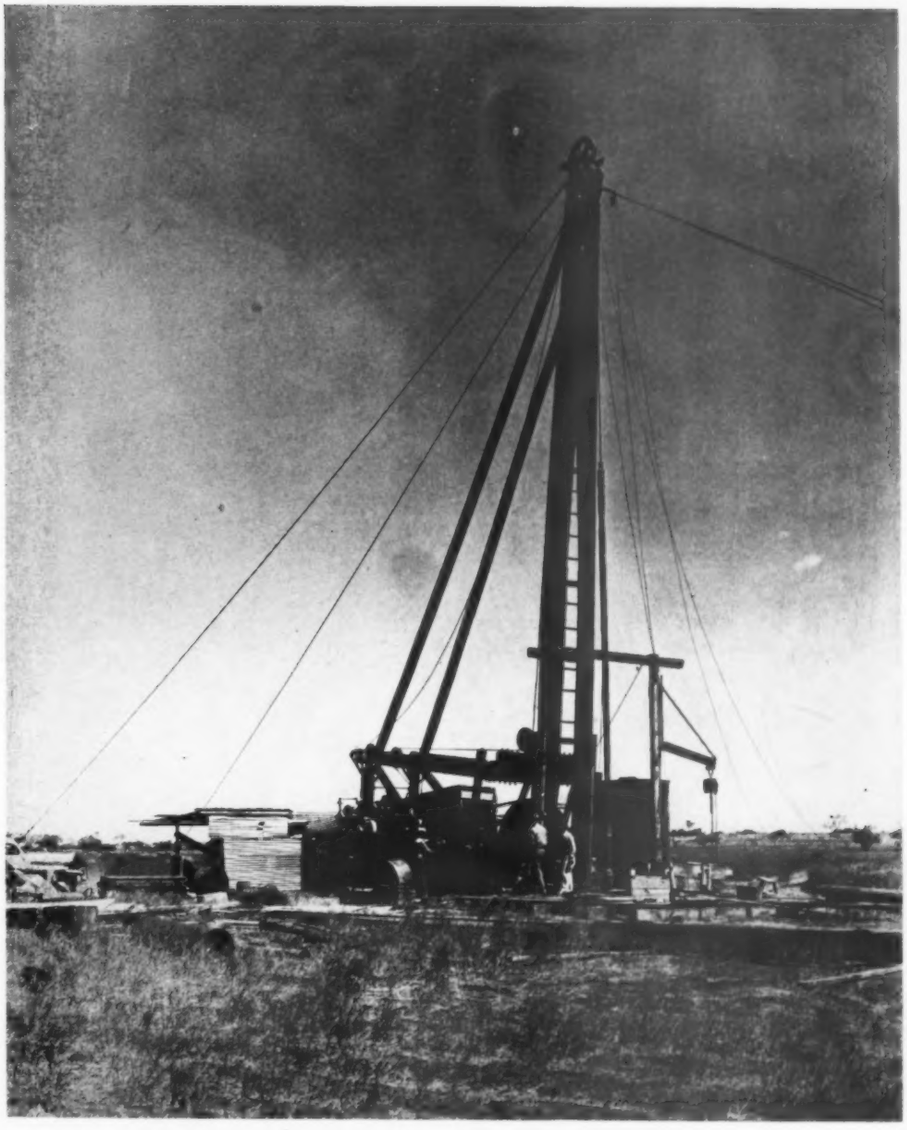
A medium weight rotary drilling outfit during a cementing operation. This is typical of several hundred such rigs now in operation in the United States as is the driller whose team work with the drilling crew is vital to the 12,000 ft. hole he is making. Temporary splitting up of experienced crews presents an important problem to the contractor.



United States can meet all current needs is a comforting thought in this time of uncertainty.

Last fall the office of Petroleum Coordinator tentatively asked the petroleum industry to drill at least 30,000 wells in the United States. Special emphasis was placed on the necessity for increased wildcatting activity, even if this had to be done at the expense of ordinary field development. The program called for by the government plainly showed some concern over the adequacy of developed reserves. Robert E. Allen, Director of Production for the Office of Petroleum Coordinator, stated recently in an address before the annual meeting of the American Association of Oilwell Drilling Contractors:

"I am here now to talk to you about some of the problems that our industry faces in the days ahead, and you are well aware by this time that there are very serious problems with us already. You have always shown yourselves to be well endowed with the qualities of courage, daring, ingenuity and a willingness to learn and try new things. I can promise you that from what I know of the path that lies ahead, you are going to be called upon to use those qualities to the limit. Upon your shoulders rests a burden and a responsibility which is going to become heavier and more important as the weeks roll by. The problem that lies ahead of us has been stated bluntly and briefly as just this: we must drill more wells, produce more oil, develop more proven reserves, obey sound conservation principles, do it all quickly and somehow do it with less material, particularly with less steel. That sounds like a big job and it is a big job. You and I have both heard much about the shortage of materials and the necessity of saving steel for armaments."



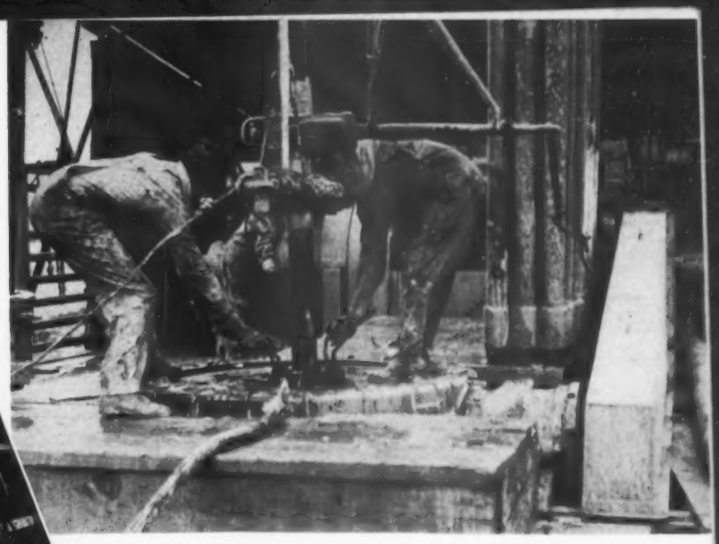
Portable drilling outfits such as this spudder play an important role in the cable tool development of many shallow fields.

In most of the principal producing areas, the drilling contractor holds the key to any development program. He must furnish equipment suitable for each operation, adequately maintain such equipment, and complete wells in an acceptable manner. To do this, the drilling contractor must be assured of necessary replacements while drilling on approved locations. There are around 2500 drilling contractors in the United States. This surprising total includes organizations equipped to meet every drilling requirement. They normally employ between 75,000 and 100,000 people, and actually support several times that number. Between 4,000 and 4,500 rotary drilling rigs, and between 2,800 and 3,200 cable tool drilling rigs are available for immediate use in the United States, and of these tools drilling contractors own and operate about 75 percent. A very light weight rotary drilling outfit costs about $25,000; a medium weight rotary drilling outfit around $60,000; a very heavy type steam drilling rig up to $125,000; a gasoline or butane rig about $140,000; and a heavy diesel-electric rig represents an outlay of almost $200,000. Cable tool drilling rigs cost from $7,500 to $25,000; but in their place they are as essential to maintenance of oil reserves as rotary tools. Obviously, these values represent original cost, and should not be construed as the present worth. All drilling equipment depreciates rapidly and replacements are numerous. A rotary drilling contractor with five active rigs steadily employs from 70 to 90 people. Some of the largest drilling contractors each employ up to 400 skilled workers. These crews are trained and coordinated over a long period, and every contractor is reluctant to disband an efficient crew when activity declines. The drilling contractor's desire to keep busy is not altogether a selfish one. His crews are built up and trained over a long period of time, and every contractor feels a sense of responsibility to his men. Drilling crews draw high wages, but they average working only from 7 to 10 months per year. If forced to curtail operations to an absolute minimum, skilled drilling employees probably would seek work along other lines. If such a development should occur and the need should arise later for intense field activity to develop new oil reserves, the drilling contractor could easily have trouble in assembling competent crews to carry out necessary drilling.

Available drilling equipment in the United States is adequate for carrying on normal drilling operations, with the exception of repair stocks. With the government trying to conserve vital materials of all kinds, it seems possible there can be some type of distribution or division that will put into service drilling tools already available. Obviously, during ordinary times it would be a case of every contractor for himself and the equipment companies for all, but during the present emergency the use of drilling tools now available should come first. The equipment

Travelling equipment includes several expensive items that move from a point near the derrick floor to a point near the derrick top. This picture was taken from the derrick floor and shows in action the travelling equipment of a heavy rotary drilling outfit.

manufacturers also are anxious to keep their organizations intact, and they deserve consideration in any plan that stops or sharply curtails plant operations. To stop the output of major equipment items might prove a dangerous precedent in the case of a long war. The service life of a drilling rig is difficult to determine as one unit. Many of the major items last several years, while other items wear out in a short time. Frequent replacements naturally will be necessary to carry on normal drilling operations in any district. The average service life of a drilling outfit is four or five years, when based on normal rates of depreciation. This means that while some of the items must be replaced several times in four or five years, other parts will remain serviceable through the entire depreciation period. Such items as wire line, bits and drill pipe



A heavy rotary drilling outfit, such as the one shown on the left above, costs about $100,000. The average service life is about four years. Many parts wear out several times during this period while other parts remain serviceable during the entire time. Running drill pipe in and out of the hole, as shown at right above, requires a substantial part of the total drilling time. This is particularly true when it is necessary to change bits frequently.

are not ordinarily depreciated so much on a time basis as on a service basis. Equipment receiving fairly uniform service lasts longest and usually is depreciated on a time basis. Boilers, derricks, pumps, engines and draw works have a comparatively long service life.

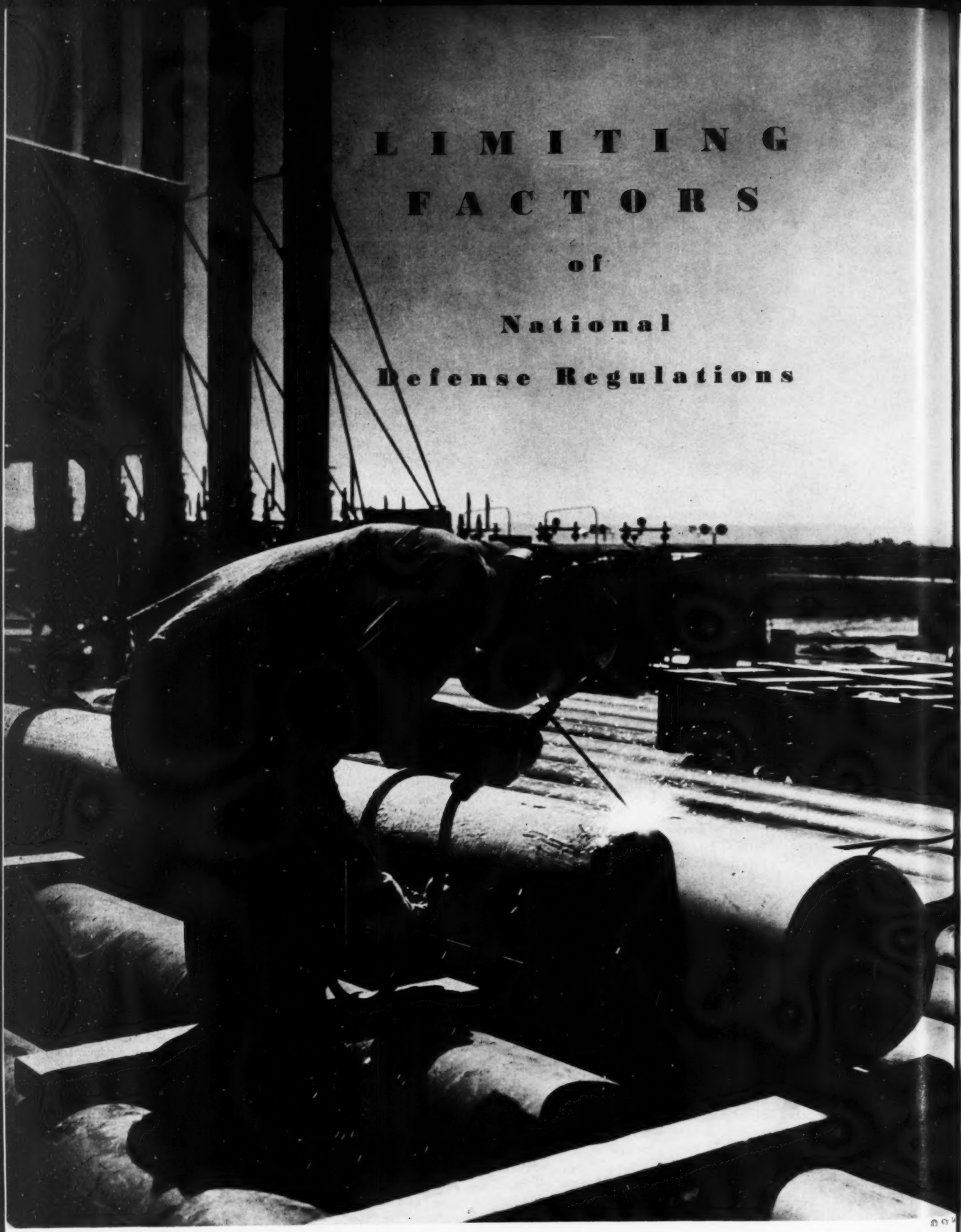
How can the drilling contractor best serve the interests of his country during the present emergency arising out of the world conflict?

It is much easier to ask this question than to answer it, but the drilling industry can and must render a real service that will fit into our general war effort. To do this he must drill necessary wells with less equipment than he has used before; and he must be prepared to pursue wildcatting activity in all promising areas. He must also cooperate with his fellow contractor and the company for whom he works. To do this does not mean that he must entirely discard the competitive aspects of the business. The desire of the Petroleum Coordinator's office to drill 30,000 wells in 1942, and the office of the Production Management's plan to conserve steel and vital materials necessitate a new method of attack for the drilling contractor. The original O.P.C. schedule called for a full year's drilling program in 1942, with 30 percent less materials.

The recent 40-acre spacing rule has done much to complicate present and future drilling operations. It is not within the province of this article to discuss the merits of this order but its enforcement already has affected drilling operations in all the major producing areas. In promulgating this order the government attempted with one effort to eliminate unnecessary drilling, while encouraging field operations that would maintain necessary petroleum reserves. In its original form the order simply states that each well must be supported by at least 40 surface acres, and does not take into consideration the presence of more than one distinct producing formation or the existence of an unusually thick oil horizon.

Drilling contractors are vitally interested in the government's plan to encourage wildcatting. This type of exploration is hazardous at its best, and the percentage of discoveries is very low. In some producing areas less than one wildcat well in each 50 drilled opened a new oil field over a thirty-year period. The percentage of discoveries has been increased with the application of more scientific exploration methods ahead of the drill, but even now the odds against any wildcat venture are extremely high. The continuation of normal drilling operations in the immediate future will depend largely on the attitude of oil drillers toward increased wildcatting. In some of the more remote producing districts, new oil fields will be at a disadvantage because of a lack of pipeline outlets. This condition already is affecting exploratory work in West Texas, New Mexico and the Rocky Mountains.

The total cost of drilling an oil well is divided into three principal classifications. They are labor, equipment and expense. The proportions of each vary in the several districts, and under changing conditions. A good average breakdown of costs shows labor to be about 33 percent, equipment 45 percent, and expense 22 percent. The average drilling cost in the United States is about $21,000 per well. The average depth of all wells drilled in the United States annually varies from 2,900 to 3,100 feet. This represents an average cost of about $7.00 per foot for drilling and equipping a well for production. The cost of drilling a wildcat well is always much higher than the average for subsequent wells drilled after discovery. Drilling contractors have for a generation attempted to study the hazards connected with wildcatting, and have drilled discovery wells in many of the largest fields in the country. The government's desire to push wildcatting activity while developing new oil reserves calls for closer cooperation between the drilling contractor and the oil companies having the work done. Drilling contractors during the present emergency are prompted by patriotic reasons to accept laws and ruling that are seemingly opposed to their best business interests. In fairness to the drilling contracting industry such acceptance may not prove the best course in the long run for the country as a whole. The drilling industry should hold itself in readiness for a possible upturn in field operations. The United States may soon be supplying almost all of the Allied petroleum requirements. This can be done, but a continuation of both wildcatting and field development will be required to assure adequate oil supplies for every need. The drilling industry now finds itself in a difficult position. The normal peacetime desire would be to drill the largest practical number of wells. The wartime desire is to conserve vital materials, while drilling enough wells to maintain adequate oil reserves and hold together drilling organizations. Just where this compromise should be drawn is difficult to determine at this time. The current idea that the United States can indefinitely produce twice its present output simply by "opening the valves" on wells now completed is a popular fallacy. The producing trend of any oil field over a considerable period is downward, never upward. Many flowing oil wells could easily produce twice their present output, but the greater number of pumping wells could not do so. Complete cessation of drilling activity certainly is not contemplated at this time, but care should be taken to continue all necessary development where it will do most good.


LIMITING
FACTORS
of
National
Defense Regulations

By L. E. Porter

Exploration Must Be Encouraged, Exploitation Maintained: Proper Well Spacing Programs Should Be Devised to Meet Problems of Individual Fields Instead of Relying Entirely on an All-Inclusive Per Acre Program.

THE oil industry has always been confronted with complex problems, but motivated by its almost limitless energy, it has, in due course of time, solved most of them in its own way. The present war and accompanying national defense situation have merely given rise to an immediate problem, the solution of which can best be reached by the industry itself provided those directing national defense will acquaint the leaders of the industry with their requirements and the clear-cut limitations to be placed upon materials and tools essential to such solution. The year 1942 is placing serious demands upon the oil industry, and the primary starting points toward proper coordination and progress in the present problem are an early recognition of the fundamental principles involved and the development of rules and regulations to harmonize with those principles. The purpose of this article is to emphasize two of these essentials and to weigh certain existing regulations and misinterpretations thereof which are seriously obscuring the issue to the detriment of work performance.

Those familiar with the fundamentals of the history of the oil industry need not be prodded into action to keep exploration at an efficient, high rate of activity, because without continuous exploration in likely areas, added discoveries cannot be made. It is essential that exploration be carried onward lest the golden horn of black gold ultimately prove to be empty due to lack of source material. Thus, encouragement must be offered which will be conducive to voluntary exploration. The incentive for such development is in the continued lifting of priority restrictions on materials as far as is possible in keeping with national defense emergencies, in order to permit their use in necessary exploration for proper oil reserves to meet future emergencies. The minimization of these restrictions should not be limited to the discovery well but should also allow an orderly allocation for the primary patterning of the newly discovered pool. Therefore, in formulating regulations, the discovery well should be considered only a portion of the primary objective.

Legitimate exploitation and proper remedial and deepening work are likewise essential to promote the proper oil reserve backlog to counteract constant withdrawals of oil and to provide safeguards against serious errors in any concept of existing tangible reserves, as well as to help overcome any shortage due to failure to keep new discoveries apace with consumption. Such exploitation and repair work have proved essential in maintaining oil reserves in the past when no national emergency existed; today when it does exist, and our calculations are based on grim reality, we must employ the same safeguards to see that tangible reserves are available if and when needed. This type of exploitation automatically overcomes losses through natural depletion, casing failure, edgewater encroachment, and other chronic irregulatrities normal to the operation of an oil field or pool. Only too frequently do we accept the presence of tangible reserves, forgetting that long periods of work and planning have been consumed in creating their availability. Naturally involved in legitimate exploitation is the proper spacing of wells, which is treated in the paragraphs to follow. Involved also is the adoption of pressure maintenance or gas recycling in certain areas to recover the greatest amount of oil possible with the least expenditure of materials and money.

Drilling and producing conditions in the Gulf of Mexico, conducted from barges differ widely from those encountered in Western Kansas, for example: there is reason to believe that a well spacing program might be devised for each area instead of relying on a straight per acre basis over the whole country.

The adoption of such production methods is to be encouraged, even to the point of giving proper consideration in the production picture to those operators who, in pioneering, risk their capital toward such conservation. From the business viewpoint, there seems to be little difference between the employment of new production practices such as pressure maintenance and pioneering for added reserves through exploration—except that the risk is less in the former case. If the industry and those involved in national defense fully realize the advantages of pressure maintenance in new and high pressure fields and the millions of barrels of reserves that can be made available through its adoption, the practice should receive the same encouragement under Order M-68 (and subsequent orders which may be issued) that has been given to exploratory projects. Secondary recovery methods apparently are finding ever-increasing favor, and these should be given similar encouragement whenever the availability of steel makes this possible.

Probably few problems within the oil industry have been more greatly misconstrued than those relating to estimates of crude oil reserves and the effect of well spacing upon them. At various times during the past twenty years, general formulas have been devised and terms have been used in connection therewith that have all the earmarks of those used by the patent medicine salesmen; that is to say, formulas have been paraded forth as a cure-all for the problem under consideration. There is no disputing the fact that the fewer the wells involved in well spacing, the more it constitutes a step toward conservation of materials to be used in the oil industry; but it does not necessarily hold that it is the proper procedure for building up a tangible oil reserve essential to national defense. Unless reserves are made tangible, it is questionable whether they should be considered a part of the national defense problem. Conservation Order M-68 as applied to production material for the oil industry sets forth, among other things, an exception permitting the use of those materials by operators who drill and complete their wells in conformity with a uniform well-spacing pattern of not more than one well to each forty acres. It provides a like exception for the operator drilling any discovered or undiscovered natural gas field, other than a condensate field, if the well conforms to the uniform well-spacing pattern of not more than a single well to each 640 surface acres. References to well-spacing patterns are also found elsewhere in the various orders and subsequent amendments.

It appears, then, that in obtaining materials well spacing is an important point to be considered; and it is likewise important that those formulating rules to govern the operations realize that no uniform rule to determine proper well spacing has heretofore been devised that will apply equally in all pools and fields. The spacing pattern depends entirely upon individual characteristics of pools and fields. It is assumed that it was not the intention of those preparing Order M-68 to limit drilling to a pattern of not more than one well to each forty acres, but rather to use the one-to-forty as a basis and any deviation therefrom to be justified by the proper presentation of data. The basic idea of bringing the well-spacing problem into future development is commendable, and if uniformly adopted throughout the oil industry, it should do much to eliminate any aggravation of improper spacing methods. While it is true that many interesting discussions and formulas have been presented for determining proper well spacing, the writer is unaware of any effort which has been more of a guiding light in such work than certain rules which were developed by Mr. Willard Cutler (Bureau of Mines Bulletin No. 228, published in 1924). Some discussion of Cutler's rules has been had in the past few years, and it has been fairly well shown that deviations therefrom have occurred; but notwithstanding, it still appears that Cutler's rule is fundamental and needs only the establishment of proper factors to be used in connection therewith. Only when it is considered that Cutler established his formulas long before core analysis, bottom hole pressure, and other modern data were available is it realized that Cutler is to be credited with a considerable degree of advanced thinking along the lines of well spacing. During recent years, the exploitation of properties has gravitated toward the establishment of well-spacing formulas based more or less on Cutler's initial endeavor. It is not the purpose of this discussion to advocate the application of any variation of Cutler's rule, but to point out the necessity for it or some equally applicable rule in connection with the work which must be done under the regulations of M-68 in order to justify drilling more than one well to each forty acres in any pool or field.

The fact that greater recovery per well or per acre constitutes only a part of the problem must be fully realized in justifying the development of a uniform spacing pattern. The increasing use of pressure maintenance methods in high pressure and condensate fields likewise exerts an additional influence in establishing the data for proper well spacing and emphasizes the fact that due consideration must be given to this subject by those weighing the relationship of pressure maintenance to well patterns. It is important, then, that both operators and the administrators of M-68 regulations fully realize that the oil industry must progress much farther than it has in order to ascertain the solution for any pool or field under consideration. For example, close well spacing in one field may prove to be an act of conservation in the strictest sense and an economic boon to the operator, while in another field the same spacing may prove economic suicide. The oil industry is a complex one at best, and perhaps there is no production problem as involved as that of well spacing determination for any given property, pool or field. To solve it properly, it is necessary to run the entire gamut of petroleum or production engineering knowledge. Failure to consider all phases is to fall far short of an equitable determination of the problem of proper well spacing.

Of these fundamentals and their relation to existing regulations, it may be said in conclusion that : (1) It is essential that any regulations for the oil industry should invite exploration for added crude oil reserves. (2) It is fundamental that existing government regulations be adjusted to invite legitimate exploration in order to provide necessary safeguards for keeping tangible reserves in strict readiness for

Left, moving equipment into the Bradford field in Pennsylvania prior to drilling: Below, the driller keeps an eye on the weight indicator while drilling a deep hole in California. Though conditions differ widely in these two fields both are at present subject to the 40 acre spacing rule issued by the Office of the Petroleum Coordinator.

national defense purposes, and to maintain already-developed properties in shape to conserve a natural resource during its exploitations. (3) Operators should be ready to develop, and those administering the regulations to accept, the necessary data from which to design proper well spacing programs for any property, pool or field, and should not rely too implicitly upon a margin of safety of any set well-spacing-per-acre program that is all-inclusive.

Portability As A Factor In Emergency Drilling

Restrictions on Normal Production Drilling May Make Equipment Available for Expanded Wildcatting and Workover Operations—Adaptation Of Light Rigs To Deeper Drilling.

DEVELOPMENT of drilling equipment and technique which has made available to the oil industry modern drilling machinery and practices has progressed during the past fifteen years through improvement of existing methods and not by changes in basic principles involved. Under normal conditions this progress could have been expected to continue through improvement of materials used in the machinery required and through improvements in drilling practices made possible by more efficient drilling equipment. Present demands on the steel and allied industries caused by the war effort will, for the immediate future at least, retard this type of development.

Another factor probably will be the availability of present drilling equipment and personnel made idle by the recent restrictions imposed upon drilling by government authority. The reduction of production drilling, even though emphasis is being placed on expansion of wildcat work, is decreasing the total drilling effort being expended. Whether or not this effect is a desirable one under present conditions is outside the scope of this discussion, but this change in drilling requirements will, within the drilling branch of the industry, cause a substantial percentage of the drilling equipment and personnel recently employed in production drilling to seek employment elsewhere. Additional wildcat activity may absorb some of this equipment, some may be used in more intensive workover in producing fields, and some of it will be utilized in production drilling in new fields found at depths for which it is suitable but there will remain, in addition to these possible uses, a substantial amount of equipment and personnel that will remain idle under present conditions until a broader application for them can be found.

This idle equipment and the fact that capacity of the steel and allied industries will be occupied on other work, indicates that the normal improvement in drilling equipment will be retarded, but also emphasizes the necessity of a solution for the problem of using this equipment and trained personnel and suggest that new techniques may be developed in order to adopt existing equipment to broader use, both in production and drilling operations.

Some assistance in this solution may come from rearrangement of the machinery to make it readily adaptable to either drilling or workover work. The suggestion has been made that since most workover work requires less power and auxiliary drilling equipment, the designing of skids and substructures, so that the units of equipment needed can be added or taken off as the work requirements demand, would increase the usefulness of the available equipment. Increasing the portability of the available equipment has been receiving some study and as a result progress has been made in increasing the efficiency of drilling equipment and no doubt additional progress along this line will broaden the field of application and make it possible to use equipment that would otherwise be idle because of its being at present suitable for only specialized work. Increasing the drilling range of available medium to light equipment may assist in its utilization on work for which it is now not considered suitable. Even if some sacrifice in drilling time is required in drilling at greater depths, the greater range in drilling depths may be found desirable during the shortage of equipment.

The obvious methods for reaching greater depths with this size equipment is through the use of smaller drill pipe and more lines. Changes of other units of equipment to at least partially correct for deficiencies encountered in deeper drilling suggest themselves and may be resorted to to meet special problems as they arise. It is not to be expected that all drilling rigs can be made to fulfill all drilling requirements, but improvements that can be expected in the immediate future under present conditions would be logically expected from adapting available equipment to a wider range of application and from improvements in technique in the use of this equipment.

Since workover work requires less power and auxiliary drilling equipment, and with the decrease in production drilling more workover and wildcat drilling is anticipated, portable designs should permit the addition of extra units of equipment where these are required and their ready removal where they are not needed.

Transferring Well Allowables To Conserve Steel

By H. M. Staggs

The Atlantic Refining Company

FORTUNATELY, conservation in the production of crude oil had been an increasing practice for many years prior to the beginning of World War II. As a result, millions of barrels of oil which otherwise would have been wasted or left unrecoverable in original reservoirs are now in our underground reserves and readily available for use in the present emergency. We have great reserves, such as East Texas, Yates, and other fields where vast quantities of oil can still be produced by natural flow. This oil, now possible to produce by natural flow, would have required expensive artificial lift had no conservation in the form of proration been enforced for the past eight or ten years. Seldom in the history of the world has the wisdom of any practice been so conclusively and quickly proven as the conservation of reservoir energy in producing crude oil.

Due to the present war emergency, the amount of steel available for use in the petroleum industry is limited to those amounts absolutely necessary for wildcatting, production of existing wells, and some development under wider spacing rules. The amount of steel necessary for production equipment can be held to a minimum by a stringent application of conservation so that the flowing life of our fields can be lengthened to the maximum possible interval and the installations of steel consuming artificial lift equipment thereby greatly reduced. Great energy in the form of high pressure gas is available for artificial lift operation. Where available, such energy should be utilized in preference to the development of energy by means of heat engines, which require installing, highly skilled labor, and manufacturing facilities for their creation that could otherwise be used in defense work. Future artificial lift installations should also be carefully considered from the standpoint of weight and the lightest type installed that will effectively operate in a given area, thus saving steel for the necessary ships, tanks and guns.

Conservation in oil production may be defined as the production of the greatest possible amount of oil with the smallest possible amount of energy. This is of the greatest importance for several reasons, chief of which are ultimate oil recoveries and more oil produced by natural flow. The most satisfactory means of accomplishing such conservation would be by Unit Operation, where the entire pool is operated under one management. This would make possible long range planning for the best interests of all concerned. Some progress has been made along these lines in recent years. However, complete Unit Operation is not fully accomplished except in a few instances. Therefore, more progress is much to be desired. In the absence of Unit Operation, some accomplishments that would aid in conservation would be to create units within a field for operating purposes whereby the allowable of such units could be produced by any well or combination of wells in the unit to conserve reservoir energy. Thus, gas energy could be conserved by producing lowest gas-oil ratio well or wells in each unit. The transfer of allowables from high volume water producers to other wells on a lease as is suggested in some fields will assist in the conservation of both reservoir energy and artificial lift equipment. Where wells are closely spaced, some system of allowable transfer to offset wells on the same lease would free large quantities of artificial lift equipment for use elsewhere. Where possible, wells should be reworked and natural flow reestablished in preference to the installation of artificial lift equipment. In the production end of the business our motto should be "Keep 'Em Flowing to Keep 'Em Flying."

In spite of an ever rapidly increasing number of petroleum products and their uses, the producers of crude oil have met all demands and at the same time have continued to perfect the practice of conservation to a high degree. During all of this time the price of petroleum products to the motorist and consumer has been reduced.

Unlike coke, iron and some other vital products, to locate reserves of petroleum requires much time, trained technical effort, and expenditure of money. Undoubtedly, the undiscovered oil reserves are deeper underground than the average existing reservoirs. To place a petroleum reserve in the known class rquires proof by drilling. It is believed that the entire cessation of the search for petroleum reserves, even with curtailment of civilian use of petroleum products, would result in natural decreases in our known reserves.

Present priority ratings are favorable to research, exploration, and development on 40-acre or wider, well spacing. This will result in lessened drilling activity and, therefore, we may expect that the present drilling equipment should be adequate to carry on for awhile at least.

It is probable that pools of high octane crude and pools of low pour point lube crude will have preference over all other fields and the producing industry will assist in all possible ways to increase output of essential military products.

Much of the work in conservation has been, and is being done by engineers. A large percentage of these engineers are now in the armed forces and many more are slated for those forces in the near future. For an industry so vital in the national defense as the oil producing industry, it has been very modest in attempting to secure exemptions from military service. Exploratory drilling and keeping the existing wells producing at a minimum cost require well trained and experienced engineers. It is to be hoped that a sufficient number of such employees can be retained by the industry to prevent any serious breakdown in the efficiency of the field operations in the production of crude oil.

Conservation, so necessary in the present emergency, emphasizes the desirability of unit operation; where complete unitization is impossible, much can be accomplished by creating units within a field where the allowable of all wells in the unit can be produced by one or more of the wells.

Sustaining Productive Capacity During the War

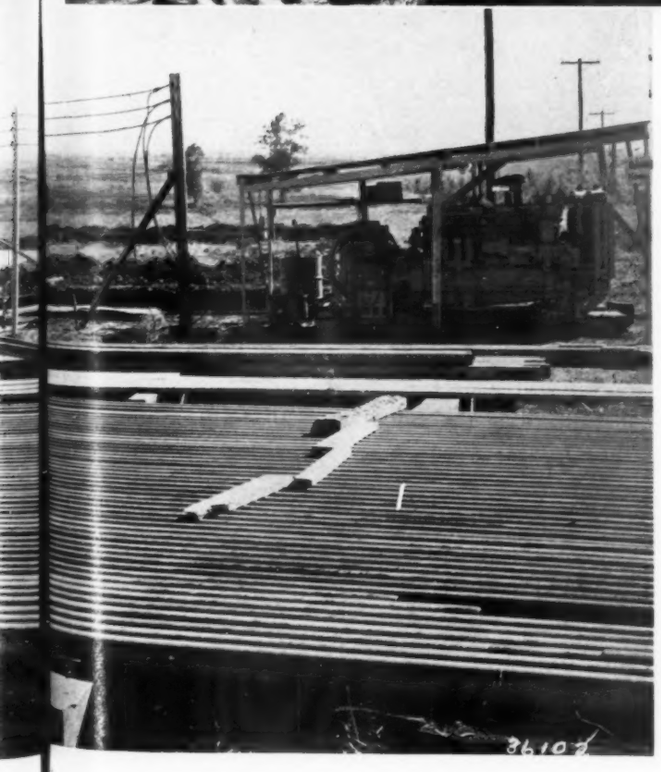
By Jack H. Abernathy

Chief Petroleum Engineer
Superior Oil Corporation

ANALYSIS of the various governmental regulations issued thus far pertaining to the petroleum industry shows clearly that the cessation of development work so evident since the first of the year was anticipated, and was the end sought in preparation of such orders. The many inequities arising from rigid orders, and public inconveniences and industrial and personal dislocations occasioned, are all to be ignored as inconsequential in the broad plan leading to victory in the war. Decisions made as to the necessity for a given action will be based solely upon the answer to the question "Will the proposed step aid directly in the production of war material?" When this test is applied to a proposed well, if the war effort does not immediately need the specific crude from the particular well in question, then the steel and other critical materials required should be conserved for direct war use.

It is true that wildcatting is desired to find reserves for future years, yet it is now plain that the development of new fields discovered by wildcatting and drilling to final density in old fields are both to be discouraged for the duration of the emergency in order to save vital materials. Although drilling activity will be largely suspended, we must be able to produce sufficient volumes of oil for all military requirements and essential civilian uses. Since our entire mode of life is integrated with the automobile, perhaps the major essential civilian use of petroleum products is for transportation to and from work. Each individual operator or oil company must consider all means of preserving his ability to produce larger volumes of oil if the need arises. The need must be filled even if the tools, pipe, rubber, and alloys formerly used are scarce or unobtainable. It should be noticed that performing an operation with the least expenditure of materials is not necessarily with the least expenditure of money. Evidently, some oil fields now developed may be called upon to produce at rates which might be considered inefficient in normal times. Along with many other ideals and concepts, conservation may become a casualty of war.

Means available for increasing productivity of producing wells fall into two classes: (1) Producing from a new pay zone; (2) Increasing production from the present pay. Within these broad classes, however, divisions are numerous. In the first class, the well may be drilled down to tap known or suspected deeper horizons, or conversely, the well casing may be opened opposite zones which were penetrated in the original drilling. Methods for two-zone production which have been recently developed will, no doubt, find an increasing use. In drilling deeper, some of the problems encountered are: protection of the zone from which production had previously been taken, in order to avoid contamination and other damage to the formation; proper casing, cementing, and mudding practices to minimize use of materials and to avoid damage to equipment already in the well; and working out fishing jobs and completion and production problems occasioned by the small holes that must necessarily be cut in most deepening work. Fortunately, great advances in slim-hole drilling technique have been made in the past two or three years. The specific means for opening the casing and exposing an upper zone may be a small shot of nitroglycerine or gelatine, one of the several gun perforators now in general use, or perhaps a long-knife casing ripper. Other methods may be em-



Steel that might normally go into uses pictured above and to the left—casing and drill pipe—is now urgently needed for tanks, guns and ships. The decreased quantity available for the oil industry is being released on the basis of 40 acre spacing for new wells, not because this is necessarily the best spacing pattern, but because that is all the steel available for the oil industry.

ployed when arrangements are made at the time casing is run in the well. For example, a special alloy pipe section may be removed with acid, or another type may be readily cut out with a wall scraper or mill. Choice of the most desirable means must be made with full knowledge of the particular condition to be encountered, and detailed study of the individual well is required. Hand in hand with these operations, other questions arise, such as methods for plugging back and water shut-off. The geologist must play an important part in such operations. Wells in many older fields were drilled as rapidly as possible to the objective pay and well logs are either incomplete or erroneous, so far as upper formations of potential great worth are concerned. In these cases the relatively new technique of radioactivity logging has already proved its value in locating the various strata behind the pipe. Radioactivity records can usually be successfully correlated with electrical logs, now familiar throughout the entire industry, run on nearby wells drilled in recent years.

In increasing production from the present pro-

ducing horizons (the second class mentioned above) an almost unlimited number of alternatives may be considered. The problem in a specific instance may be primarily that of water encroachment, in which case the point of water entry must be determined. Water may enter above, with, or below the oil. After settling this question, then the method for exclusion of the water must be decided upon. The well may be plugged back, using lead, cement, or a variety of other materials. A squeeze cementing job may be utilized. In some cases it has been found necessary to cement a liner in place and gun perforate the oil zone in order to exclude water from above, or above and below the oil zone. If the water enters with the oil, and the formation will allow quantity withdrawals of fluid without caving or sanding up, it may be decided to install high-capacity producing equipment and lift large volumes of water to obtain increased oil production. Surprisingly good results have been obtained by this method in certain areas, where the ratio of barrels of water produced per barrel of oil drops as total fluid withdrawal is increased. Other wells may produce too much gas for efficient operation, and the means for reducing gas-oil ratios may range from a simple control of the production rate or the use of packers and other mechanical devices, to the plugging by cement or other means of the formations through which gas enters. The cases cited above relate to the same general phenomenon—the well under consideration produces too much, or too high a proportion of some reservoir fluid other than oil. While an entire book could be devoted to the technology of corrective operations on wells of such type, an even larger group of wells are not capable of producing large quantities of fluid. To increase productive capacity of low-volume wells, energy in some form may be added to the reservoir to stimulate fluid movement through the pay, or the resistance to fluid movement offered by the formation may be decreased to make it easier for oil to flow through the pay and into the well. Obviously, at times both means of increasing production are used simultaneously. Repressuring (pressure maintenance) and water flooding are often used to stimulate productivity and may add very materially to producing capacity, but these operations are complex and require care in application and improperly used can result in serious damage to the reservoir. Just as an inflamed appendix calls for the services of a competent surgeon, so does secondary recovery require the expert attention of a qualified petroleum engineer. Shooting the pay with nitroglycerine or other explosives or acidizing with hydrochloric acid are frequently resorted to to increase the rate of flow from the pay to the well. In older wells, solvents for removing paraffin encrustation on the face of the pay are sometimes used. Often, removal of mud or sand which has accumulated in the bottom of the hole is accomplished by baling or by circulating water, mud, or oil which may be heated or cold.

Medium mechanical rigs with emphasis on economy such as the Caterpillar shown on the left, and low cost cable tool outfits for tailing in such as the Bucyrus-Erie rig shown below contribute to economy in fuel and equipment required in the present emergency.

Yet another group of wells exists in which decreasing production is largely the result of mechanical failures. The screen may be corroded or plugged with sand, shale or gypsum. The screen may have collapsed by moving sand or cut out by erosion resulting in a sanded-up condition. In areas where corrosive water or electrolytic conditions are encountered, holes or breaks may occur in the well casing itself. Similar difficulties may appear owing to casing wear if the well is baled or swabbed for extended periods of time, especially if the hole is crooked. Some of these mechanical difficulties are almost indistinguishable at the surface from other types of well troubles, and great care must be exercised in determining the repair procedure, otherwise irreparable damage may be done to the well.

Thus the war period will see an intensified study of the individual well and its peculiar characteristics. Tools and methods available today to the producer are many and adequate for most conditions encountered. In the application of these methods to the specific instance, great ingenuity is required and proper choice of procedure can only be made in the light of all available information. It is safe to say that the production man, petroleum engineer, and geologist will each find ample use for his talents in meeting the nation's oil needs during the emergency, even though major drilling programs will be deferred until the war is won. We must and we will have a flood of oil available to supply ourselves and our Allies now that much of the East Indies' oil production cannot be used, and may be entirely lost. If we will allocate a part of the skill and intelligence previously directed to discovery and development to an intensified study of present wells, we need not fear the demands of the coming difficult years.

Thirty-eight men dumping sacks on a cement job prior to the advent of bulk cementing.

Operating Economies Aid

NATIONAL DEFENSE

By Nicholas A. D'Arcy, Jr.
Emsco Derrick & Equipment Co.

California Operators Set Place In Steel, Cement Savings and More Efficient Handling of Limited Number of Drilling Rigs.

IN 1941 oil well equipment manufacturers were keenly handicapped by loss of competent engineers to National Defense projects and by limitations in material available for use. Drilling departments of producing companies and drilling contractors were faced with similar problems necessitating greatest economy in the use of all equipment. These forced economies resulted in increased unitization and mobilization of drilling equipment, drilling with casing to eliminate drill pipe and bulk cementing.

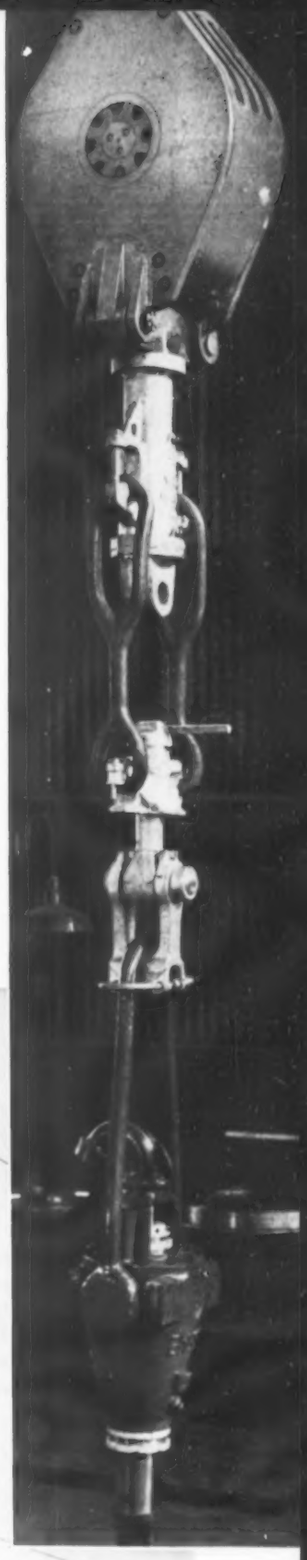
In light of the national emergency the development of drilling with casing in place of drill pipe is worthy of close investigation, as it completely eliminates duplication of tubular goods in drilling. Late in 1940, a major oil company substituted 4½ in. casing for drill pipe, and during 1941 proved to their satisfaction that it was economical to use 4½ in., 12.6 lb. casing to drill 7⅝ in. hole, 5½ in., 17 lb. casing to drill 8½ in. hole and have conducted experiments with seven inch 26 lbs. casing when drilling 10⅝ in. hole. The casing is standard Grade J with ends upset sufficiently to provide a thickness of metal under the threads equal to the normal wall thickness of the pipe. The threads are a standard cut by Pittsburgh, which is coarser than the regular pipe thread but a comparatively fine thread without the conventional tool joint shoulders. Drilling with casing is a development based upon the drilling costs of one major operator. The cost of the casing used runs approximately 15c per foot higher than standard casing and if the normal cost of drill pipe exceeds 15c per foot of hole drilled, drill casing should be given close consideration for economy and present availability.

In addition to the purely monetary standpoint, it has several interesting features whose value is difficult to determine. Transportation costs on pipe are materially reduced as formerly it was necessary to haul to each location a string of drill pipe and then a string of casing. Setting casing is greatly simplified. At the completion of the well it is only necessary to come out of the hole on the last trip, remove the drill collars and rerun the drill casing which is already standing in the derrick made up into its maximum lengths. Drill casing allows for the circulation of a greater volume of mud at lower pressure than circulation

through drill pipe. Four and one-half inch casing has approximately the same inside diameter as 5 9/16 in. drill pipe, yet the hole drilled is only 7⅝ in. diameter. It has been estimated that the upward velocity of the mud in the annular space between the drill casing and the wall of the hole often exceeds 1,000 ft. per minute, which provides for very efficient removal of cuttings. Fishing jobs have been materially reduced as compared to the average for this particular concern when using drill pipe. No special equipment is necessary on the rig for handling casing. It takes considerable less effort to tighten the threads than it does with conventional tool joints and tong practice has been adjusted to the new threads.

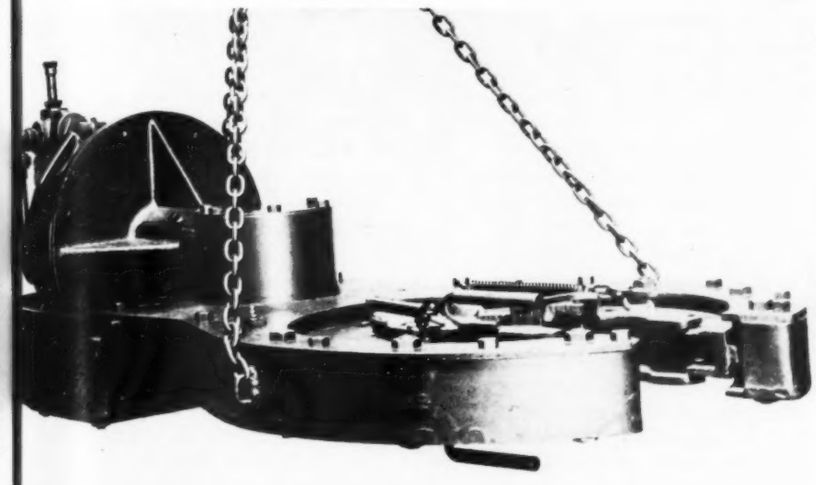
An interesting development in connection with the drill casing is the use of a set of steam driven rotary casing tongs which apply constant torque each time a joint is made up. Care must be taken not to apply excessive torque and spread the boxes as there are no shoulders for the joints to buck up against, as in the case of standard tool joints. The rotary tongs also provide for faster spinning up and safer operation. When the joints are made with the standard catline and tongs, the number of wraps required to make the joint are materially reduced and only two wraps are taken on the cathead when completing the joint with standard tongs.

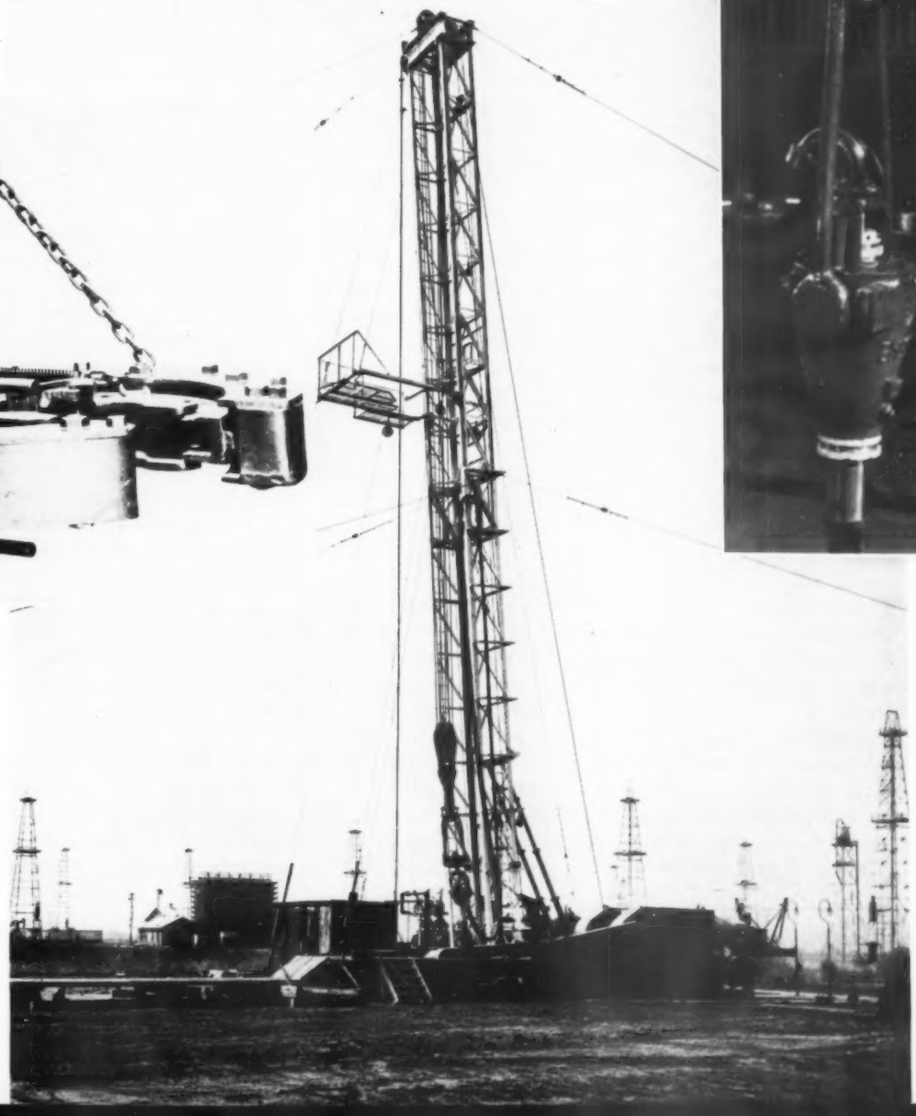
moved complete units over the rolling Poso Hills in California on Athey Wheels. In assembling this unit it was determined that four major pieces of equipment were necessary. The derrick unit consisted of an 87 ft. steel derrick complete with crown block, traveling block, rotary machine, drawworks and 185 h.p. internal combustion engine. This unit was mounted on a substantial sub-base incorporating built-in track-laying wheels. The front wheels were mounted to allow for steering and the rear wheels were held rigid in line with the longitudinal axis of the unit. While drilling the entire unit was jacked up to take the load off the wheels. When the well was completed the jacks were removed and a tractor attached to the draw-bar at which time the unit was ready to move. Although an 87 ft. derrick was used, the center of gravity of the entire unit was only approximately 16 ft. above the ground, which made it possible to move over the rolling hills with comparatively little road-building. The second unit consisted of the pipe rack which was also permanently mounted on track-laying wheels. When the pipe was removed from the derrick it was laid in place on the movable pipe rack which placed it in position for moving without any further handling.



Right, short coupled 100 ton drilling hookup with connector direct connected to lower clevis of travelling block. Below, light unitized portable rig with 90 ft. mast; drawworks and 200 h.p. motor permanently mounted on semi-trailer. Second trailer carries two 7¼ in. by 10 in. slush pumps and two 145 h.p. engines.

Below, rotary casing tongs powered by steam or compressed air; particularly adapted to making up drill casing whose fine thread requires many revolutions.





Entirely new standards of portability and unitization of complete drilling rigs has been established during the past year. This rapid development in portability and unitization has eliminated the old practice of rigging up a complete derrick head of the drilling well, thus saving one complete set of drilling equipment. It has not been uncommon to skid derricks from location to location on level ground but this year an enterprising operator

Above, 87 ft. derrick unit with drawworks, engine and sub-base permanently mounted on Athey wheels (left) and slush pump and engine similarly mounted.

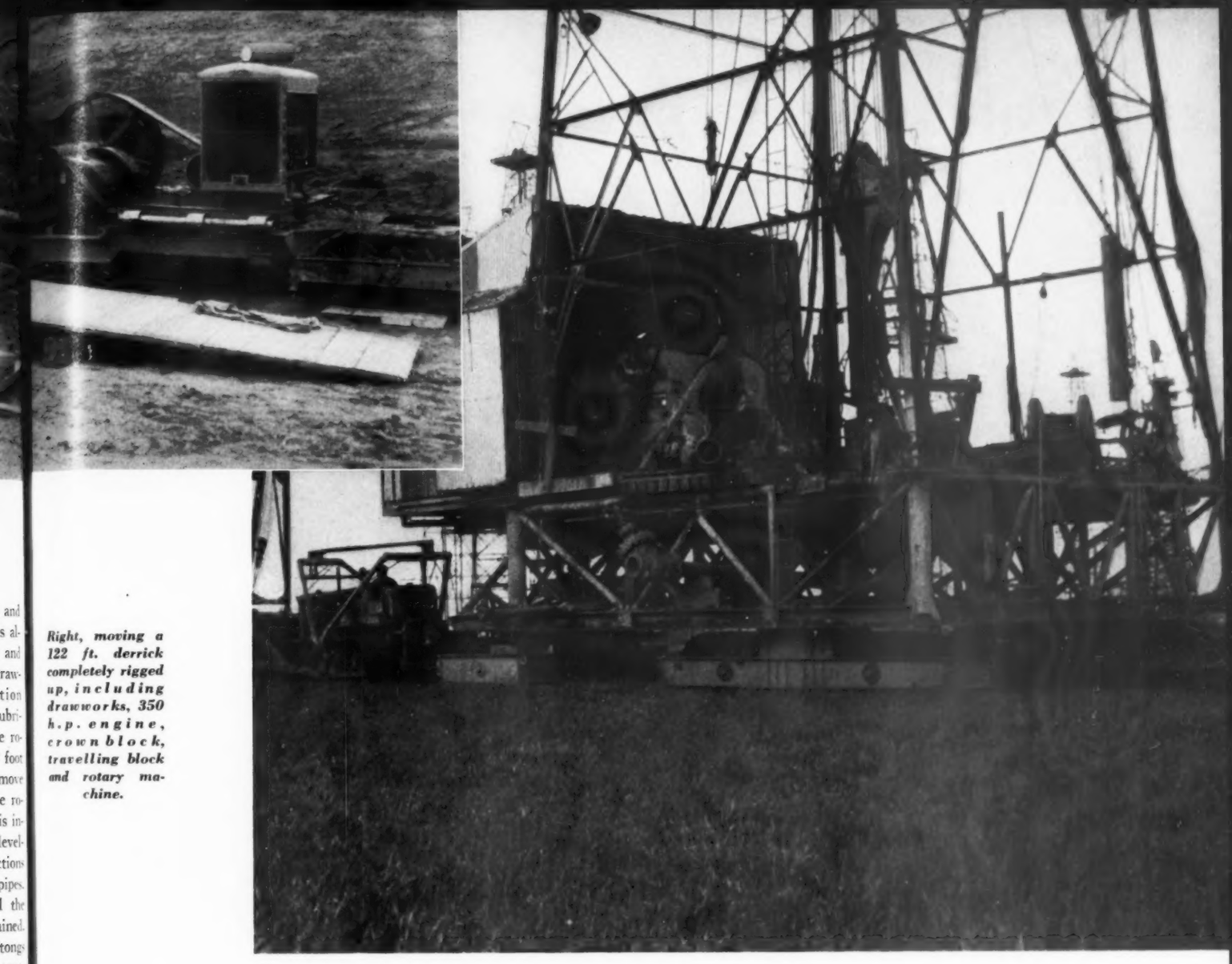
The third piece of equipment consisted of a 7¼ by 14 in. power pump with its internal combustion engine, manifolds, mixing gun, suction pump and tool box. In moving the slush pump unit, it was only necessary to disconnect the discharge lines and elevate the suction pipe. The fourth unit consisted of a 20 ft. by eight foot wide doghouse mounted on wide flange steel wheels. This entire assembly was built in such a way that the component parts of each of the four units could be dismantled into sections, falling within the California highway limitations for size and weight. This equipment has been moved for distances up to 2½ miles and the time required from completion to spudding in has been less than 12 hours representing a substantial saving.

In the Dominquez field the same operator has mobilized a 122 ft. derrick unit complete with crown block, traveling block, draw-works and 330 h.p. internal combustion engine. The pump unit is also mobilized consisting of a 7¼ by 18 in. slush pump powered by a 330 h.p. internal combustion engine and a 6¾ by 12 in. power slush pump with a 150 h.p. internal combustion engine. The derrick unit is moved by jacking the entire assembly approximately 36 in. off the ground and installing suitable Athey wheels. It is then hauled to the next location by a tractor or tractor and trucks. The derrick unit can be moved a distance of one-quarter mile in less than an hour. The track-wheels are then removed, the derrick lowered and the wheels returned to the original location where the pump unit in its entirety is jacked up, set on the wheels and in turn hauled to location. Development of the above rig necessitated design of a special sub-base for the derrick to transmit the loads to the track-wheel supports. It also required a special sub-base upon which the two pumps with their respective prime movers could be moved. Thirteen moves have been made in the Dominquez field with this equipment. Before the equipment was mobilized it was standard practice to rig up a complete derrick ahead of the well being drilled. This practice is now discontinued due to the speed in which the mobile unit can be moved and rigged up by use of the Athey wheels.

Within the past few months a very interesting light duty drilling unit has made its appearance, all being mounted on two pneumatic tired semi-trailers. This drilling unit consists essentially of three parts. The first trailer carries 200 h.p. internal combustion engine, draw-works, 90 ft. telescoping and folding mast, crown block and traveling block. The second unit incorporates two slush pumps, each powered by a separate engine and a small lighting plant. The third portion of this rig consists of the two piece substructure with rotary machine, miscellaneous guards and operator's platform around the entire drilling unit. The slush pump unit consists of two 145 h.p. internal combustion engines, each of which drives to a 7¼ by 10 in. power slush pump. The slush pumps are set side by side and by cutting off the inside projection of the drive shafts it was possible to reduce the overall width of the pumps to 7 ft. 10 in. The engines are alternated, one driving through a standard clutch power take-off facing the right-hand side of the trailer to the right-hand pump. The other engine with its clutch power take-off on the left-hand side of the trailer drives to the left-hand pump. With this compact unit all compounding manifolds between the pumps can be left intact, thus eliminating all field connections with the exception of the intake and dicharge hoses. The slush pump unit also includes a small portable power driven generator set for lighting.

The draw-works unit is quite typical of the portable units, incorporating the 90 ft. telescoping and collapsible mast. In order to reduce the overall width of the unit and still mount a gear transmission on the fly-wheel of the 200 h.p. engine, it was necessary to remove the radiator and mount it at right angles to the engine. This allowed for completely enclosing the engine and draw-works into a compact unit. The draw-works is, of course, equipped with friction clutches throughout and oil tight, fully lubricated chain drives with the exception of the rotary drive. In order to stay within the eight foot California road limit, it is necessary to remove the rotary drive in its entirety including the rotary friction clutch on the draw-works. It is interesting to note the tong counterbalances developed for this rig. They consist of two sections of casing mounted to slide on inclined pipes. These casings are filled with water until the necessary counterbalancing weight is obtained. These counterbalances are attached to the tongs by means of a light cable passing over sheaves fastened to the finger board. Any standard truck with a fifth wheel attachment for hauling semi-trailers can be used for moving this equipment from location to location.

A major operator in the Santa Maria field is now moving a 700 h.p. draw-works unit, consisting of two internal combustion engines, compounding transmission, draw-works and sub-base as a single unit. With this unit a special sub-base is laid down, the height of this base being equal to the height of a low bed semi-trailer. The entire draw-works and motor unit is then pulled on to the semi-trailer by means of a winch line. This piece of equipment could not be moved over the California highways as it exceeds road limitations in height, width and weight. Another California operator has constructed a special truck ramp which enables any standard truck to back up to high derrick floors making the truck bed level with the derrick floor. In this manner heavy pieces of equipment such as rotary machine, crown block and traveling block can be skidded directly from the truck bed to the derrick floor without any lifting or special equipment. This



Right, moving a 122 ft. derrick completely rigged up, including drawworks, 350 h.p. engine, crown block, travelling block and rotary machine.

type of ramp is particularly effective on the large steam rigs where the complete unit is knocked down between each move.

Bulk cementing eliminates much of the waste prevalent when using sacked cement. Broken sacks, damaged by water and incomplete emptying of sacks is eliminated and even the saving in paper sacks is worthy of consideration in these trying times. Bulk cementing is one development that won the immediate favor of the drilling crews, by elimination of man-handling cement sacks, and from petroleum engineers because of the uniformity of cement slurry produced. All major California fields are now prepared to deliver bulk cement at a saving of time and material to the operator. The new bulk cement wagons and modern cement pumping units are synchronized with fool-proof controls to provide a uniform cement slurry for any ratio of water to cement. It is interesting to note that the speed which these units can deliver cement to the well is generally governed by the available water supply, not by the capacity of the unit. In the deeper and more critical wells in the San Joaquin Valley, the operators are now installing special water lines to provide sufficient volume of water to allow for the mixing and placing of 100 sacks of cement per minute with two bulk mixing units. No longer is there a wastage of cement due to broken sacks, incomplete emptying of sacks nor damage from moisture. New bulk cement wagons operate as efficiently in a downpour as on the dryest day. Should the operator for some reason decide that he does not care to cement at the time the job was originally planned for, it is only necessary to send the bulk wagon back, whereas previously it was necessary either to load hundreds of sacks of cement on a truck or store it at the rig location with the hazard of loss.

The wide-spread use of internal combustion drilling equipment was necessitated by completely redesigning the cement pumping units. These units now often comprise a water tank, two cement pumps and two internal combustion engines to power the pump. These are all operated through ingenious controls that insure maximum pressure and volume in the discharge with a uniform slurry. By the operation of simple controls located on the cement pumping unit, it is possible rapidly and efficiently to change the ratio of water to cement in the slurry.

California operators have saved many tons of tubular steel through the use of drill casing and have released drilling equipment for exploratory work by efficient unitization of existing equipment and by an ingenious and practical means of making all drilling equipment readily portable. The bulk cementing operations have released considerable cement for national defense projects. These aids for cooperating in the national emergency are another example of the oil operator's desire to do everything possible to assist the nation in producing oil economically.

IMPROVED BESSEMER PROCESS

Furnishes Steel to Meet Exacting Oilfield Requirements

By J. Jay Dunn & E. C. Wright

National Tube Company
Pittsburgh, Pa.

DEEP DRILLING requires pipe of high collapse resistance, refining operations at high pressure and temperatures require tubing of high tensile strength, and other oil industry operations that involve low or subzero temperatures require steels that do not become brittle at these temperatures. Heretofore there has been only one source of steel of these high qualities. That source is the relatively expensive open hearth process, which delivers a product free from the impurities that cause weakness and adds the qualities that give strength. There is now added another and more convenient source. The Bessemer process has been improved to a point where it can deliver a product equal to open-hearth steel. Instead of puddling furnaces, a modern Bessemer steel plant need add only a large ladle and methods for measuring accurately small amounts of molten pig iron, and it may then turn out steel billets admirably adapted for making the highest quality of seamless tubing, for the oil industry and other industries that must use the best.

The first steel pipe manufactured in this country was made from Bessemer steel. Since that day in 1887 in Wheeling, West Virginia, when butt-welded pipe was first made from Bessemer steel skelp, this material has been used satisfactorily for the manufacture of both butt-welded and lap-welded pipe. Prior to that time all pipe was made of wrought iron, as only furnace-welding processes for forming pipe were available and furnace welders thought that steel could not be readily forge-welded. Pipe is still being made by the lap-weld and butt-weld processes, but the quantities so made have gradually decreased during the last few years due to the preference of engineers for seamless and electric-welded pipe. Moreover, a large proportion of the pipe made by the lap-weld and butt-weld processes is now made from open hearth steel. As a result, the amount of Bessemer steel used in pipe manufacture has decreased to a very low point. Probably 90 percent of all kinds of steel pipe is now made from open hearth steel.

During the period in which the methods of pipe manufacture were being radically changed, the applications of pipe were also being profoundly altered. The efficiency of equipment using enormous pressures, such as boilers, cracking stills, chemical plants, and in the drilling of deep oil wells, resulted in a large demand for pipe of very special characteristics. Many of the present-day uses of pipe are such that welded Bessemer steel pipe is entirely inadequate. This is most definitely manifested in several A.S.T.M. specifications and in A.S.M.E. Boiler Code requirements, which limit the use of such pipe to restricted temperature and pressure conditions. The failure of Bessemer steel welded pipe to keep pace with increasing requirements is due largely to the properties of the acid Bessemer steel as made in the United States. Practically all of the acid Bessemer steel made is of the so-called open or undeoxidized type of steel. In the trade it is usually termed "rimmed", "capped", or semi-killed steel. This type of steel is quite low in carbon content, usually under .10 percent carbon and rarely over .20 percent carbon, and consequently of low strength. It is also high in oxygen, and as a result, is frequently subject to erratic brittleness and is less reliable than open hearth steel for cold forming. For example, Bessemer steel skelp or plate is undesirable for electric-welded pipe, as the plate does not cold-bend prior to welding as uniformly as open hearth plate of the same hardness or strength. Furthermore, the toughness of undeoxidized Bessemer steel is known to be very poor at temperatures of 32 deg. F. or subzero temperatures. Occasionally, extreme brittleness has been encountered in Bessemer steel at low temperatures. There are strong prejudices among engineers against the use of Bessemer steel on this account. The high oxygen content of undeoxidized Bessemer steel also leads to the false assumption that it is dirtier than open hearth steel of the same analysis. The manner in which the steel freezes in semi-killed or rimmed steel ingots develops undesirable blow holes and segregations of carbon, phosphorus, or sulphur, which are harmful to portions of the product rolled from this type of ingot.

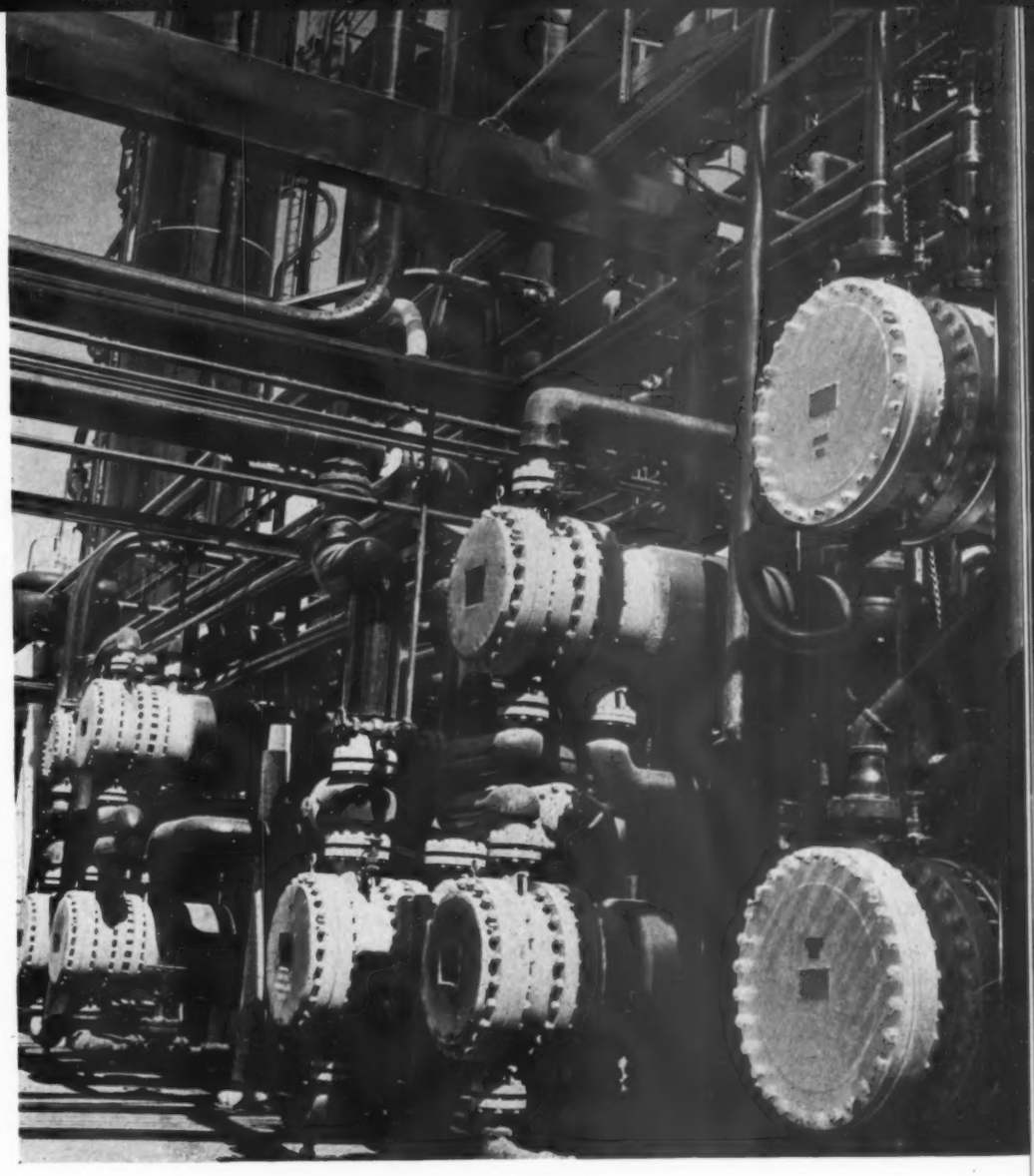
Figure 1, the left hand illustration shows a 4 in. by 4 in. billet from the center of a rimmed Bessemer steel ingot: the right hand illustration shows an 8 in. round billet from the center of a killed open hearth steel ingot.

The introduction of seamless steel pipe was largely predicated on the development of the open hearth steel-making process. The difficult forging operation involved in piercing a solid billet requires a steel of uniform density and consistent forging characteristics. Improvements in open hearth and electric melting practices have aided the extension of the seamless process to undreamed-of sizes and lengths of pipe, and today seamless pipe can be made from almost any analysis of steel melted in the open hearth or electric furnace. The principal reason for this lies in the fact that all of these steels are now made of the thoroughly killed or fully deoxidized type of steel. Many attempts have been made to make seamless tubes from acid Bessemer steels. The results have always been inconsistent and yields of good pipe extremely erratic. Such tests have always been made on undeoxidized

Bessemer steels almost identical with steel used for pipe skelp. The first known attempt to make Bessemer seamless pipe occurred in 1906 and the scrap piles of succeeding years could testify to the hundreds of subsequent failures. As far as is known at the present time, no undeoxidized Bessemer steel is used for seamless pipe manufacture for the reasons outlined above.

The fundamental difference between deoxidized or thoroughly killed steel and undeoxidized or open steel is the crux of the whole situation. The deoxidized steel is freed of its oxygen and it freezes in its ingot mold without blow holes, and with moderate segregation, and a deep shrinkage cavity which must be cropped off. The open or undeoxidized steel freezes with numerous occluded blow holes, segregation adjacent to the ingot skin, and a small shrinkage cavity. The resulting steels rolled from such ingots differ greatly in texture, density, and uniformity. Etch tests are shown in Fig. 1, which exhibit the great variation in cross-sectional structure between billets rolled from a killed steel ingot and a rimming undeoxidized steel ingot. Moreover, the bars resulting from a killed steel ingot are much more uniform from the top to the bottom of the ingot than the bars obtained from a rimmed steel ingot. As will be shown later, the total removal of the oxygen from the steel has profound effects upon its properties. The definition of a thoroughly killed or totally deoxidized steel is still not precise. It is only the recent work on the physical-chemical equilibrium processes of steel melting and deoxidation which has thrown definite light on this subject. In the past ten years numerous investigators have attempted to study the equilibrium between FeO in liquid steel and the various deoxidizing agents, such as carbon, manganese, silicon, and aluminum. A summary of this work shows quite clearly that manganese is a very weak deoxidizing agent and that steel may contain considerable amounts of FeO in equilibrium with manganese when other deoxidizing agents are absent. The most striking feature is that only by substantial additions of aluminum may the steel be thoroughly deoxidized. It has also become evident that carbon is a much superior deoxidizing agent to manganese and at some levels is equal to silicon.

The authors have found nothing in the literature which describes a thoroughly deoxidized acid Bessemer steel containing less than .50 percent carbon. In the early days of the steel industry Bessemer steel rails were manufactured, usually with a carbon content above .50, by means of pouring a molten mixture of spiegel and pig iron into full-blown Bessemer heats. It is doubtful whether steel so made could be designated as fully killed or thoroughly deoxidized, since aluminum was not even available in the period between 1880 and 1900 when large quantities of such rail steels were made. The reason that fully deoxidized Bessemer steel of low carbon content has not been previously described is obvious. The blowing of molten pig iron in the Bessemer converter gives a complete elimination of silicon and manganese, and the vessel is usually turned down at a carbon content approximately .06 percent. Depending upon the degree of over-blowing beyond the carbon change point in the flame, the FeO content of the blown metal must vary between levels .20 percent to .40 percent. Regardless of the individual blower's skill in detecting the change or the accuracy of instruments recently developed for this purpose, the blown metal is always high in FeO. Assuming the highest content of .4 per cent FeO, the amount of FeO in a ton of steel would be eight pounds. Theoretically, this should be thoroughly deoxidized with an addition of two pounds of aluminum per ton of steel. Actually, an addition of this amount of aluminum is entirely insufficient thoroughly to quiet the steel and even additions of as much as six pounds of aluminum per ton will not prevent ingots poured after this treatment from rising in the molds. The discrepancy must be due either to a higher content of FeO than estimated, or more probably to the extremely low efficiency of aluminum additions. Aluminum is so light and melts at such a low temperature that it tends to escape from the ladle without completely acting on the FeO in the steel.



The new process, described in this article, makes steel available from a modified Bessemer process for seamless high pressure pipes in refineries.

In the previous discussions it was emphasized that carbon is a very effective deoxidizing agent. Using this principle, additions of carbon in various forms to blown acid Bessemer metal were attempted, and it was found that by the judicious use of carbon combined with conventional amounts of regular deoxidizing agents, such as silicon and aluminum, Bessemer steel could be thoroughly killed, poured in regular ingots with full hot tops, and rolled exactly like open hearth steel into satisfactory seamless tubes. The principle of this practice can best be represented by an example. Two 25-ton blows of Bessemer metal are treated with 2,000 lb. of molten pig iron, added in each vessel after blowing, and then are poured into a 50-ton ladle. The mixing of

the blown metal and hot pig iron in the vessel is almost instantaneous and the elimination of carbon and oxygen in the FeO in the form of CO gas is extremely rapid. In fact, a large puff of flame over the top of the converter occurs almost instantly. In 100,000 lb. of blown metal containing .4 percent FeO, the amount of FeO is approximately 400 lb. In 4,000 lb. of molten pig iron with 4 percent carbon and 1 percent silicon, there are 160 lb. of carbon and 40 lb. of silicon. The 400 lb. of FeO should require 66 lb. carbon for deoxidation. This calculation comes out almost exactly in practice, although it is doubted that the FeO reaches as high a figure as .4 percent or that the carbon deoxidation has such a high efficiency, as the 40 lb. of silicon will also deoxidize 200 lb. of FeO. The 160 lb. of carbon in the molten pig iron is partly eliminated as CO gas and the carbon content of the resulting steel increases from approximately .06 percent to .16 percent. This increase in carbon content of .1 percent in 100,000 lb. metal requires 100 lb. of carbon. After this reaction, the steel may be treated with the proper additions of ferro-silicon to yield .15 to .25 percent silicon, 1 to 3 lb. aluminum per ton of steel, and sufficient ferro-manganese for the final manganese content desired in the steel. The carbon content of the steel can also be raised by increasing the amount of molten pig iron used to any level desired. The steel finished by this practice is then poured into ingots with hot tops, and etch tests on the resulting billets show the dense cross-section structure of a fully killed or deoxidized open hearth steel similar to that shown in Fig. 1. The carbon treatment may be made in various ways, such as by the use of coal, graphite, or petroleum coke, but the best results have been obtained with the use of molten pig iron on account of the higher carbon efficiency of this kind of addition and the thorough mixing which occurs between the blown metal and the hot metal.

The analysis of a heat melted as described above is approximately .16 percent carbon, .50 percent manganese, .20 percent silicon, .04 percent sulphur, .08 percent phosphorus, and .014 percent nitrogen. This is exactly analogous to the composition of an open hearth killed heat, except that the phosphorus content remains practically unchanged from that of the original hot metal charge to the converter, and the nitrogen is picked up from the air in blowing. Steel made of this approximate composition has been rolled successfully into many sizes of seamless pipe, and has been cold drawn with satisfactory results into very small sizes of tubes. Experience with thousands of tons of this steel in making seamless tubes for many different uses has been entirely satisfactory.

The element of phosphorus has been considered for many years as highly injurious to high quality steel. Investigation of properties of the steel described herein indicates clearly that this old assumption is absurd and that phosphorus in the amounts found in this type of steel is not detrimental, but actually is a highly desirable alloying addition. The authors are uncertain as to how high a level of phosphorus can be permitted, but the indications are that at least additions of phosphorus up to .2 percent will have a definite engineering value for many purposes. The beneficial effect of phosphorus has also been recently pointed out by several other investigators, particularly H. W. Gillett in an article entitled "Phosphorus as an Alloy Element in Steel" in the June 1935 issue of Metals and Alloys, and by C. H. Lorig and D. E. Krause in the July 1936 issue of the same publication.

The physical properties of this steel should be of great interest to the pipe-consuming trade. Analyses of over 300 tensile tests show that for a carbon range of .12 to .18 percent manganese range of .35 to .56 percent, and a phorphorus range of .07 to .09 percent, the steel has an average yield point of 55,000 and a minimum yield point of 45,000: Average tensile strength is 75,000 while minimum is 66,000: Average elongation in two inches is 35 percent with minimum elongation of 25 percent. At this low carbon content the steel is readily weldable and is also satisfactory for cold-forming operations such as bending and cold drawing, consistent with the yield point exhibited in the tests above.

It was stated earlier in this paper that undeoxidized acid Bessemer steel is frequently subject to unexplained brittleness. The thoroughly deoxidized steel described in this paper seems to be entirely free of this characteristic, and the authors believe that many of the vagaries of ordinary undeoxidized Bessemer steel are associated with its oxygen content. The elimination of this oxygen by the melting practice described also definitely eliminates the susceptibility of Bessemer steel to treacherous brittle failures. This question has been thoroughly investigated on hundreds of heats of killed Bessemer steel by means of impact tests made at various temperatures between 100 deg. F. and 50 deg. F. On page 84 impact properties of undeoxidized open hearth steel, undeoxidized Bessemer steel, killed open hearth steel, and killed National Melt Bessemer steel are displayed. It will be noted that the National Melt deoxidized Bessemer steel in the hot rolled state has impact properties at temperatures as low as 50 deg. F. which are higher than the normalized 95,000 minimum tensile strength killed open hearth steel. The impact properties of the National Melt killed Bessemer steel are further improved by normalizing treatments which refine the grain. It is believed that these results clearly indicate that low temperature brittleness of Bessemer steel of this type is non-existent, and the fact that the undeoxidized open hearth skelp has extremely low impact properties at subzero temperatures is a further evidence that oxygen is the main element influencing this characteristic. A further interesting feature of the physical properties of this deoxidized Bessemer steel is that it

High pressure equipment on deep drilling operations can also be made from the new Bessemer process. Heretofore such steel had to be made by the costlier open hearth process.

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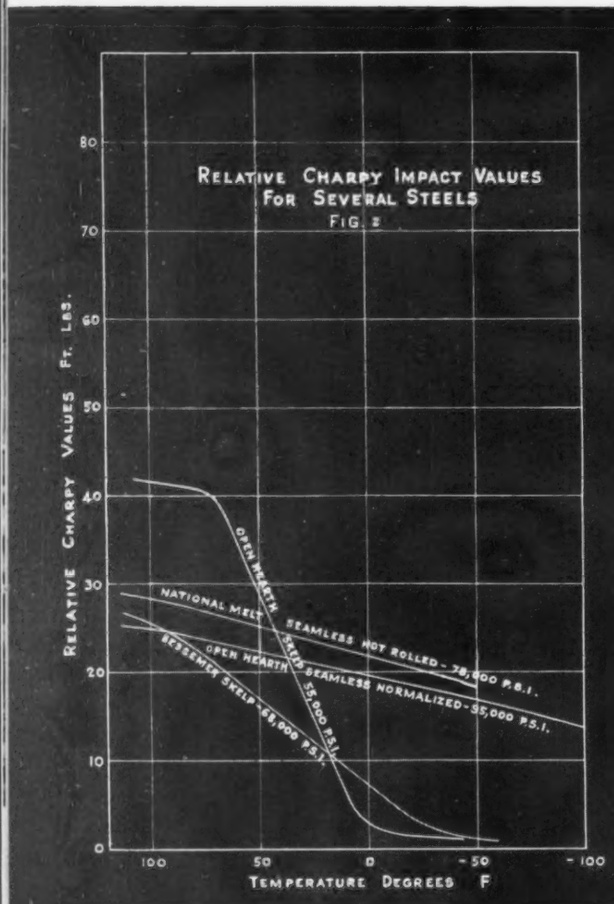

Figure 2: relative charpy impact values for several steels.

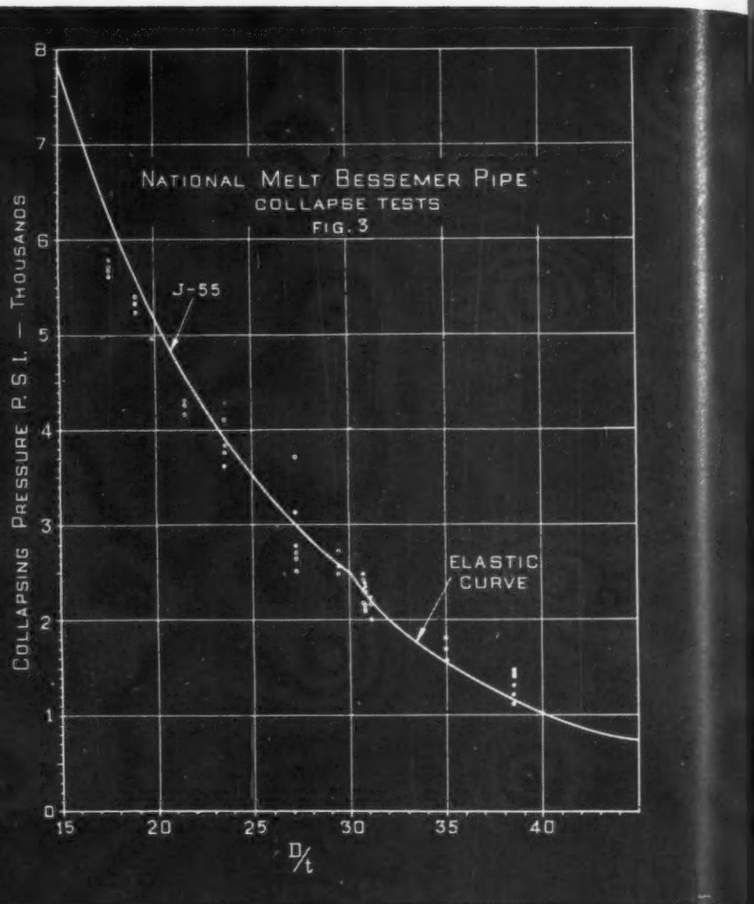

Figure 3: collapse tests on national melt Bessemer pipe.

exhibits a high elastic ratio and a high true proportional limit as measured in carefully plotted stress-strain diagrams of tensile tests. In the average tensile test values given previously, the ratio of the yield point to tensile strength is .733. In open hearth steel of the same tensile strength rolled in similar sizes, this ratio is only .625. This is of particular advantage in pipe used for structural purposes, such as tubular piling and drive pipe, and for pipe subject to high pressures, such as line pipe. The greater stiffness due to the high elastic ratio has made this type of pipe extremely satisfactory for drive pipe, which is pounded into the ground much like piling. This type of steel in drive pipe exhibits much less crushing and deformation in driving the sections, and permits the use of harder blows and faster driving. Extensive investigations of the collapse resistance of pipe indicate clearly that the elastic limit or proportional limit of the pipe steel is of prime importance in obtaining higher collapse resistance. It is believed that the small content of phosphorus in this deoxidized Bessemer steel is the main factor contributing to the high elastic ratios and high proportional limits. Collapse tests made on many sizes of pipe show that the collapse resistance of the National Melt Bessemer pipe is equal to the collapse resistance of open hearth alloy steel casing, designated as A.P.I. Grade J-55. Fig. 3 shows the collapse resistance of various sizes of casing for the J-55 A.P.I. grade. The circles along the curve show actual tests of National Melt Bessemer pipe following closely the curve for the A.P.I. Grade J-55 fully killed open hearth casing.

The high temperature properties of this deoxidized Bessemer steel have not as yet been fully investigated. Indications are that the beneficial effect of phosphorus on the short-time tensile strength and the creep resistance at elevated temperatures will be obtained. The work of several previous researches clearly indicates that phosphorus additions to experimental heats give a very definite increase in high temperature properties. H. C. Cross and D. E. Krause in an article on this subject in the August 1937 issue of Metals and Alloys, show that phosphorus additions are definitely advantageous to the high temperature strength without noticeable impairment of other physical properties. They demonstrate that a low-carbon, low-phosphorus steel has a creep resistance for 1 percent elongation in 10,000 hours at 850 deg. F., of about 10,500 lb. per sq. in. as compared to a creep rate of only .865 percent in 10,000 hours at 830 deg. F., with a load of 12,000 lb. per sq. in. on a special low-carbon steel containing .21 percent phosphorus. This represents at least 25 percent greater creep resistance for the steel treated with phosphorus.

The authors believe that the type of steel described herein exhibits a peculiar and valuable combination of properties which will make it useful for many purposes, particularly in the form of pipe. As demonstrated from the consistent results obtained on several hundred heats, the steel is easily produced and readily controlled for uniformity.

There is no greater spread in properties than is found in steels of similar strength made by good open hearth practice. The only equipment required is a modern Bessemer steel plant, a large ladle, and methods for measuring accurately small amounts of molten pig iron (500-4,000 lb.). If it should later develop, as seems likely, that even higher contents of phosphorus would be desirable in the steel, Bessemer ores of higher phosphorus content would be employed to make the iron for the Bessemer converter.

The processes and product described in the foregoing article are the subject of Patent No. 2,218,458 and pending applications.

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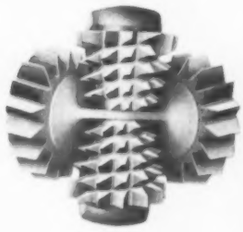

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War Stresses Need of Protecting Reserves

Industry Council Urges Measures to Encourage Exploration — Fair Prices And Statutory Depletion Allowance Held Essential.

ACTING in its capacity as advisor to the Petroleum Coordinator, the Petroleum Industry War Council on February 6, took action emphasizing the necessity of protecting the nation's oil reserves. The report on this subject, prepared by a special committee consisting of O. D. Donnell, Chairman, Frank Buttram, John F. Drake, Walter S. Hallanan, William F. Humphrey, John M. Lovejoy, Charles F. McGaha, Lawrence Vander Leck and H. C. Weiss, summed up its findings in the following seven points:

(1) That additions to the nation's known oil reserves have shown a declining trend for the past three or four years. (2) That new reserves are needed in order to meet indicated consumptive demand without waste. (3) That there is an indicated trend of increased abandonment of small wells. (4) That an increased number of wells must be drilled in order to discover the same amount of oil as formerly. (5) That premiums granted discovery wells in the form of increased allowables are an incentive to exploration. (6) That adequate prices of crude oil, which give consideration to overall costs, are essential to exploration incentive and to extend the economic life of small wells. (7) That retention of the present statutory percentage depletion allowance is essential to the above objectives.

In support of these conclusions the report itself said in part: "War conditions may temporarily restrict civilian use of petroleum and its products, but to offset this defense demands are rapidly increasing and it is possible that the petroleum resources of our allies may be lost to them through enemy action making it necessary for the United States to supply any resulting deficiency. Regardless of immediate demand oil has become one of the most critical materials in modern civilization. Long term trends of consumption are strongly upward and it becomes vital that this country not only maintain but increase its known reserves of crude petroleum.

"For all fields which have not been substantially depleted there is an approximate optimum rate of production, which if exceeded results in waste of natural energy and loss of ultimate recovery. It is essential therefore that reserves be maintained at that amount at least which will permit production sufficient to meet consumptive demand without violation of recognized laws of conservation. The data presented in the earlier section of this report indicates that the reserves of the country may soon be inadequate to supply current requirements without waste. Since the introduction and refinement of geophysics no great advance has been made in the art of oil prospecting. The record shows an ever increasing amount of non-productive drilling required for each important discovery. Less positive evidence in advance of drilling is clearly apparent. The conclusion seems inescapable that greater sums must be expended for exploration if we are to increase or even maintain the nation's reserves. The industry is qualified and prepared to increase its exploratory effort, dependent on two primary factors: first, the incentive to venture, and second, the availability of venture money. It will be seen that these two factors are closely related.

"Satisfactory prices for crude oil adequate to cover all operating and discovery costs and taxes are essential to maintain finding effort. Potentially advancing prices greatly accentuate the motive force behind such effort. The discovery rate under prices and other conditions existing during the past few years has declined. Accordingly, it is reasonable to conclude that higher prices for crude oil would speed up finding effort and discovery rates and would tend to build up reserves. The industry relies upon the over-all difference between cash income and cash outgo to provide the funds for exploration. Exploration is a controllable expense. In a broad sense that amount remaining after meeting all other expenses is allocated to exploration. With constantly increasing tax levies such remainder correspondingly decreases. Tax assessments are in fact direct charges against funds otherwise available for exploration. The present percentage depletion allowance embodied in the tax laws is a modification of the original discovery depletion allowance adopted twenty-four years ago as an incentive to stimulate discovery and development of the petroleum resources of the country. The oil industry of today stands as a tribute to the wisdom of the Congress and its tax making bodies in that it has been ever ready to meet the rapidly increasing demands of the nation, and with lower prices for its products over that period. It can be demonstrated that the establishment and application of the principle of depletion allowance in determining income tax has been one of the most effective motivating forces in establishing the present levels of crude oil reserves.

"In view of the present emergency, and in consideration of the downward trend of new discoveries against increasing demand, suggestions of the Treasury Department that percentage depletion be reduced are shortsighted and show a complete lack of appreciation of the imperative need to maintain the incentive to find new oil, which results from this provision. An increase in this allowance would be wiser over-all governmental planning. Similar conclusions can be reached with respect to the problem of extending the life of marginal wells. Incentive provided by increased prices or anticipation of higher prices serves to encourage the operator to continue wells even after their economic limit has been reached. Statutory percentage depletion allowance also serves to retard abandonment of small wells."

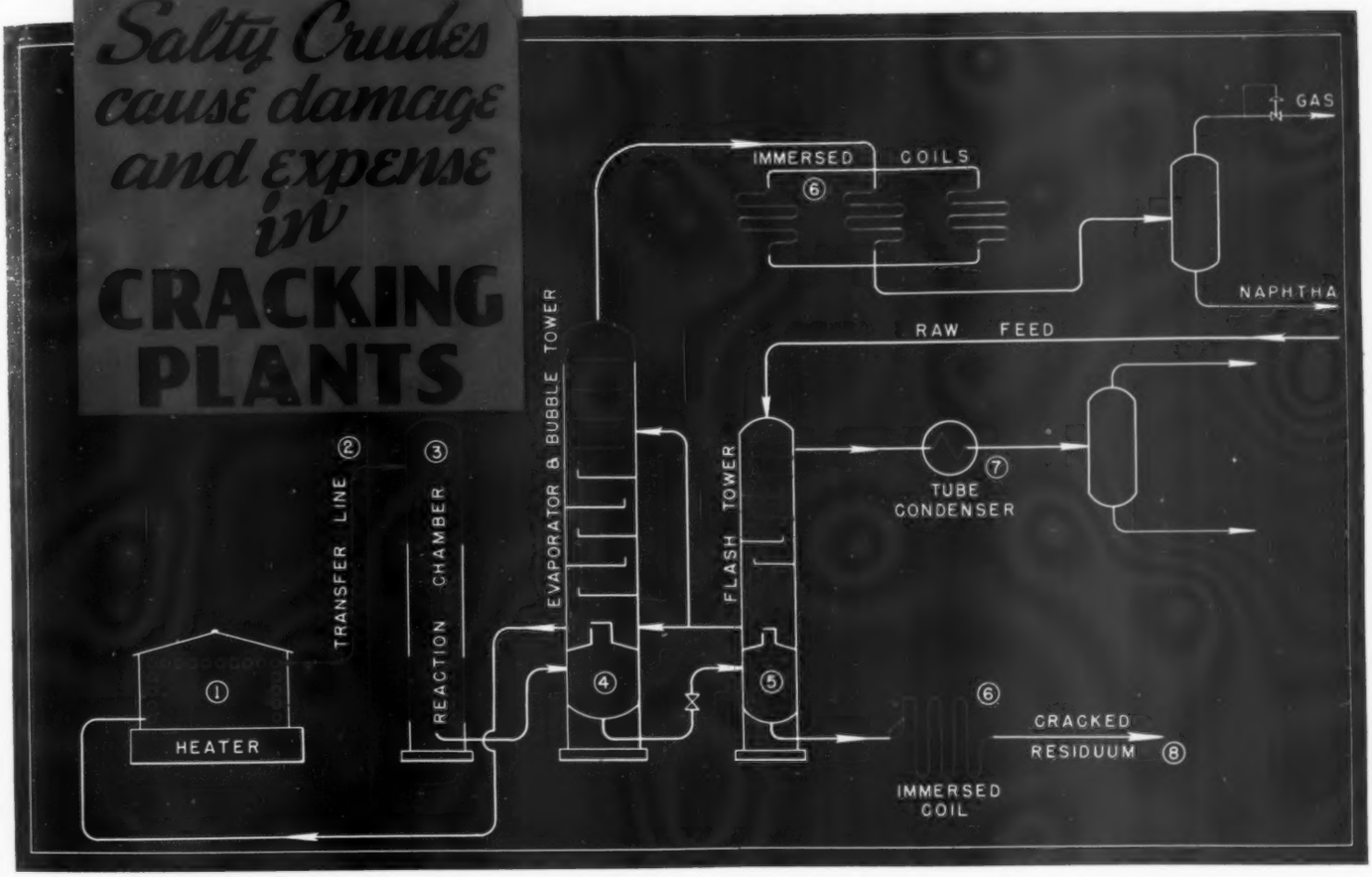
BOLIVIA SETTLES OIL COMPANY CLAIM

SETTLEMENT of the claim of Standard Oil Company of Bolivia against the Bolivian government, arising out of the seizure of the company's property in 1937, was announced in La Paz on February 2. According to the official statement Bolivia is to pay the company $1,500,000 with interest for its wells, refineries and other equipment and the company is to relinquish all rights and titles which it formerly possessed in favor of the government.

Negotiations leading to the settlement of the controversy were conducted between Foreign Minister Anze Matienzo of Bolivia and representatives of the State Department of the United States. The decision is regarded as satisfactory to both parties to the dispute. The Bolivian government has been anxious to free itself of the charge of confiscating foreign owned properties and the Bolivian congress last year authorized the national authorities to settle the case. While Standard Oil of Bolivia stated that it had expended $17,000,000 in exploration, drilling and construction during the life of its concession, it acknowledged that the small amount of production discovered and the meagre prospect of future expansion, did not justify the payment of more than a small proportion of this investment. The company was mainly concerned in removing the charge of fraud made against it and establishing the principle that orderly processes of law must be followed in acquiring its properties. Now that these objectives have been attained it is satisfied to withdraw from the country.

Following the satisfactory adjustment of the oil dispute it was announced that the Export-Import Bank would make an initial loan to Bolivia of $5,000,000, which might be increased later, for exploratory drilling and the rehabilitation of refineries. A survey to determine the extent of these requirements is now under way.

Salty Crudes cause damage and expense in CRACKING PLANTS



The water discharge illustrated above is from a Petreco Desalting plant installed at a Mid-Continent refinery. An estimated ten tons of salt per month are removed from the crude charging stock before it is pumped through the refining system. This is a good example of avoiding numerous difficulties - - - by *removing the cause.*

The above is a typical flow diagram of one type of cracking plant. The areas in red show the units that are hit hardest by salts in the crude . . . where capacities and temperatures are reduced, equipment damaged, and the quality of products impaired. Check the performance of *your* cracking plant for impaired efficiency at these points:

1. *Tube Heater:* Salt plugging, coking, and corrosion due to acid evolution, impairs heating efficiency and reduces the capacity, and on-stream time of this key unit.

2. *Transfer Line:* Salts here cause corrosion and coking. Coke formation on the thermocouple well results in defective temperature control.

3. *Reaction Chamber:* Coke of excessive hardness in the lower section, and severe corrosion in the upper area, due to salt deposition and acid evolved therefrom.

4. *Evaporator and Bubble Tower:* Corrosion and metal losses, especially in the upper section.

5. *Flash Tower:* Trays plugged with salt reduce the efficiency of the unit and impair the quality of the product.

6. *Immersion Coil Condensers:* Severe corrosion and high maintenance expense.

7. *Tube Condensers:* Corrosion, necessitating frequent replacements.

8. *Quality of Cracked Residuum:* Cracking salty crude often results in inferior fuel stocks. Asphalt solubility is definitely lowered.

All these hazards of salty crudes can be materially reduced, and eliminated in most instances, by Petreco desalting. Case histories of numerous Petreco Desalters in service prove this.

Petreco representatives are available at all times to discuss *your* salt problems. Preliminary surveys and estimates are supplied without obligation.

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Representatives In Principal Oil Fields and Refining Centers

PETRECO

DESALTING **DEHYDRATING**

WORLD OIL PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries

	U. S. BARRELS				METRIC TONS			
	January 1942 Preliminary	January 1941	January 1940	January 1939	January 1942 Preliminary	January 1941	January 1940	January 1939
United States	127,545,000	110,647,000	113,140,000	102,490,000	17,256,798	14,971,000	15,307,807	13,874,374
Soviet Union	18,428,000	19,014,000	16,969,000	17,000,000	2,527,846	2,609,000	2,300,000	2,332,000
Venezuela	21,754,050	15,249,057	14,798,667	16,489,347	3,230,000	2,264,151	2,197,278	2,438,207
Iran	6,596,056	6,560,000	6,637,503	7,100,000	861,215	870,257	880,493	940,000
Netherlands India: Sumatra	3,410,000	3,345,600	3,472,786	3,129,007	436,563	428,242	444,602	420,001
Borneo	.....	1,070,400	1,093,743	1,115,570	.....	137,038	140,026	149,741
Java	571,950	537,600	561,064	535,297	73,223	68,826	71,830	71,852
Molucca and Other	.....	60,300	59,215	49,200	.....	7,720	7,581	6,604
Rumania	3,306,000	1,961,108	3,786,908	3,934,338	448,271	265,913	513,479	537,111
Mexico	2,883,000	3,985,000	3,348,682	2,470,000	423,348	585,169	492,094	367,080
Iraq	1,500,000	1,000,000	2,615,129	2,414,878	200,507	133,672	349,556	323,797
Colombia	2,088,993	1,900,000	2,478,000	1,710,565	291,351	264,993	345,606	238,406
Trinidad	1,799,884	1,800,000	1,636,645	1,652,412	253,148	253,165	230,206	232,537
Argentina	1,839,974	1,827,660	1,674,033	2,000,000	262,104	260,350	238,466	285,000
Peru	1,147,000	1,000,000	1,154,037	1,251,162	151,415	132,013	152,737	166,281
Bahrein	620,000	628,000	631,644	647,988	84,696	85,699	86,195	88,264
Burma	659,990	648,551	644,825	650,000	91,158	89,579	89,064	89,100
Canada	843,603	802,652	486,859	531,564	107,355	102,144	61,957	67,151
Brunei	.....	472,024	488,777	506,467	.....	61,978	65,193	66,410
Great Germany: Old Reich	369,985	380,000	381,114	448,510	52,907	54,340	54,963	47,562
Ostmark	58,001	58,800	58,869	33,609	8,646	8,766	9,331	5,014
Slovakia and Moravia	8,990	9,800	10,137	10,546	1,324	1,444	1,519	1,545
Poland	232,500	320,700	331,049	326,000	31,338	43,227	44,392	43,000
Japan	227,292	218,000	225,308	224,885	32,331	31,010	32,178	32,003
British India	194,494	185,344	197,532	195,000	26,863	25,600	27,280	27,000
Ecuador	224,574	105,201	204,509	195,556	29,607	13,870	26,962	27,715
Saudi Arabia	310,000	467,900	491,663	155,605	42,303	63,851	66,604	21,100
Sarawak	.....	108,000	112,716	116,030	.....	13,816	14,539	15,214
Egypt	649,977	650,000	438,367	308,946	92,827	92,830	62,606	44,390
Italian Empire: Albania	114,979	125,000	118,358	47,402	17,233	18,735	17,670	7,075
Italy	3,720	4,000	6,650	7,511	462	497	820	933
France	40,982	40,000	42,532	42,000	5,748	5,610	5,952	5,900
Hungary	279,775	175,000	90,000	43,000	37,639	23,512	12,100	6,000
Bolivia	9,982	10,802	8,556	8,800	1,293	1,400	992	1,100
Other Countries	49,567	47,800	49,073	50,000	7,072	6,829	6,975	7,000
WORLD TOTAL	197,768,258	175,414,699	178,443,950	167,891,195	27,086,505	23,996,246	24,359,053	22,986,387

Official Crude Oil Production Figures from 1939 to 1941

	Daily Averages Bbl.		Daily Averages Metric Tons		Total Bbl.			Total Metric Tons		
	Jan. 1942	Jan. 1941	Jan. 1942	Jan. 1941	1941	1940	1939	1941	1940	1939
United States	4,114,350	3,851,589	556,670	482,935	1,405,830,000	1,353,214,000	1,264,962,000	191,377,000	182,904,869	171,152,192
Soviet Union	594,452	663,424	81,543	86,774	242,150,000	222,600,000	220,866,000	33,244,000	30,260,631	30,297,119
Venezuela	701,743	610,690	104,193	73,037	222,901,864	184,761,241	205,783,650	33,096,341	27,432,998	30,533,706
Iran	212,776	213,794	27,781	28,072	78,035,012	79,151,675	78,151,332	10,352,216	10,443,546	10,367,117
Netherlands India: Sumatra	110,000	111,855	14,082	13,814	40,827,050	40,586,986	41,557,013	5,226,865	5,172,209	5,320,320
Borneo	.....	37,939	.....	4,426	13,847,720	12,987,599	13,125,425	1,772,846	1,662,718	1,680,377
Java	18,450	18,451	2,362	2,220	6,734,781	6,514,462	6,568,714	862,218	836,982	842,237
Molucca and Other	.....	1,974	.....	249	720,780	731,746	836,114	92,277	93,569	107,047
Rumania	106,645	111,130	14,460	8,577	40,562,500	42,524,988	46,020,000	5,499,999	5,766,099	6,240,000
Mexico	93,000	112,876	13,656	18,876	41,200,000	40,314,787	39,428,141	6,049,927	5,843,395	5,794,035
Iraq	48,387	34,657	6,467	4,312	12,650,000	24,225,007	30,791,132	1,683,279	3,238,878	4,115,845
Colombia	67,387	66,963	9,398	8,548	24,441,566	25,592,890	23,857,000	3,408,853	3,569,434	3,327,336
Trinidad	57,738	58,111	8,166	8,166	21,210,644	20,218,566	19,270,256	2,983,215	2,842,918	2,710,515
Argentina	59,354	59,291	8,454	8,398	21,641,186	20,616,928	18,738,003	3,082,790	2,936,880	2,657,232
Peru	37,000	35,193	4,884	4,258	12,845,520	12,985,284	13,587,906	1,695,777	1,716,195	1,798,557
Bahrein	20,000	18,755	2,729	2,764	6,845,559	7,095,370	7,588,554	934,165	968,592	1,045,391
Burma	21,290	21,266	2,940	2,889	7,762,262	7,730,901	7,872,981	1,069,372	1,067,895	1,087,424
Canada	27,213	27,406	3,463	3,295	10,003,290	8,718,053	7,837,503	1,273,008	1,109,440	997,487
Brunei	.....	15,210	.....	1,999	5,551,743	5,729,374	5,767,227	728,959	764,006	768,320
Great Germany: Old Reich	11,935	12,158	1,706	1,752	4,437,647	4,543,955	4,487,491	634,584	653,590	647,337
Ostmark	1,871	1,896	278	282	692,240	718,494	693,247	103,195	114,045	109,904
Slovakia and Moravia	290	299	43	46	109,120	118,775	119,380	16,078	17,836	18,103
Poland	7,500	9,093	1,011	1,394	3,318,900	3,891,456	3,898,044	447,352	520,984	522,874
Japan	7,332	7,285	1,043	1,000	2,659,252	2,638,644	2,652,930	378,272	376,657	379,161
British India	6,274	6,218	866	826	2,269,650	2,249,835	2,332,467	313,488	310,596	322,160
Ecuador	7,244	4,276	955	447	1,560,998	2,349,015	2,312,118	205,800	309,686	306,824
Saudi Arabia	10,000	16,084	1,364	2,059	5,870,702	5,364,610	3,933,904	801,135	726,785	536,386
Sarawak	.....	3,594	.....	445	1,312,033	1,317,185	1,329,645	167,844	168,475	171,322
Egypt	20,967	20,982	2,994	2,994	7,658,627	6,053,367	4,603,797	1,093,773	846,514	657,570
Italian Empire: Aibania	3,709	3,784	556	604	1,381,249	1,497,124	1,393,727	207,021	224,199	208,279
Italy	1,20	125	15	16	45,894	57,350	91,330	5,699	7,110	11,346
France	1,322	1,311	185	181	478,564	496,420	506,815	67,124	69,578	70,478
Hungary	9,025	6,776	1,214	758	2,473,552	1,755,000	815,248	332,748	236,025	109,896
Bolivia	322	330	41	45	120,748	110,484	100,885	15,649	14,249	11,998
Other Countries	1,597	1,591	228	220	580,787	580,001	578,036	82,968	82,779	82,300
WORLD TOTAL	6,379,293	6,166,376	873,747	776,672	2,250,731,440	2,150,041,572	2,082,452,645	309,305,837	293,328,272	284,908,175

Detailed monthly reports were published in February, 1942 issue.

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing with Technical and Economic Aspects of the Petroleum Industry — Edited by Dr. O. W. Willcox.

GEOLOGY

Non-Marine Origin of Petroleum in China—C. H. Pan, in BULLETIN AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, Vol. 25 (1941), No. 11, pp. 2050-2068.

Inasmuch as almost all the petroleum of the world comes from marine beds, most geologists believe that all petroleum must be of marine origin. They generally do not believe that oil can originate from fresh water sediments, and that even if it did so originate, it would not be in commercial quantities.

However, there is some evidence to the contrary. The Powder Wash field of Northwestern Colorado is evidently of non-marine origin, and it has been reported that when some wells were drilled in Lake Lahontan, Nevada, oil globules came from several sands which are recent lake deposits, which is taken as evidence that oil can originate in lake deposits.

Attention is now called to the discovery in China of oil that is undoubtedly of non-marine origin. Along the border between Shansi and Shensi provinces is the Shensi basin which contains Permian deposits that are of continental origin, as indicated in part by abundant fossil land plants and coal beds, and in part by the presence of lacustrine deposits containing pelecypods and fossil fresh-water fishes. A number of wells in this basin have struck oil, but only in scanty quantities.

In Szechuan, which has a typical basin structure, oil has been found which is traced to a phase of the Tzuliuching formation of Cretaceous age, which consists of thin layers of limestone intercalated with block shales that are crowded with fresh water pelecypods. However, this Cretaceous oil has no commercial value.

It is now known that anaerobic bacteria play an important part in the transformation of organic materials into petroleum. Under anaerobic conditions, the organic materials are decomposed by bacteria into lower fatty acids, methane, carbon dioxide, and water. Anaerobic bacteria are probably much more abundant in salt water than in fresh water. That is why petroleum is generally generated in marine deposits, and oil shale generally formed in fresh-water sediments.

The writer believes that, although lake waters generally contain less salt than marine waters, the anaerobic bacteria are generally insufficient to transform the organic materials into petroleum. But if the lake water evaporated through a long period of time, the salts would be highly concentrated, and eventually the salinity of 3,000 parts per million would be reached. In this condition the anaerobic bacteria would be able to transform organic materials into petroleum. In this connection, is seen the reason why the connate water from the oil reservoir is generally saline. Both North Shensi and Szechuan produce salt, and the connate water from the old sands of North Shensi is also generally saline. This is an indication that the conditions when the Shensi series was deposited were suitable for the multiplication of bacteria, and so were favorable for the generation of oil.

DRILLING

Leak Resistance of Casing Joints in Tension—P. D. Thomas and A. W. Bartok, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual meeting, San Francisco, November, 1941.

This paper presents a survey of various factors on the leak resistance of casing joints subjected simultaneously to tension loading and internal pressure; it also presents a photoelastic study of stresses in casing joints.

Leakage tests were made on casing joints subjected simultaneously to internal pressure and increasing tensile load. The loading under pressure

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was continued until full leakage was obtained. Pressure then was removed and the joint pulled to destruction.

Results indicated that the standardized 8-pitch round-thread casing join had leak resistance in tension beyond that required in service. Yield strength of the joint was apparently the controlling factor. Long-thread joints had higher leak resistance than short-thread joints, although it was questionable if this extra tightness was of practical value. Thread lengths intermediate to API long- and short-threads appeared advisable. Thread makeup was a critical factor, three threads pullup being the optimum. Differential in taper lowered leak resistance, but this tendency was overcome by proper makeup.

Photoelastic study developed fundamental information concerning stresses in casing joints, supplementing and explaining the results of tension-leak tests. The usefulness of the photoelastic method in analyzing stresses in casing joints was pointed out.

Completion Practices Related to Well Productivity—W. J. Travers, Jr., before AMERICAN INSTITUTE MINING METALLURGICAL ENGINEERS, PETROLEUM DIVISION, Los Angeles Meeting, October, 1941.

This paper discusses multiple zone completions and gravel packing in the light of experience obtained in California.

The importance of speed in completing wells with a water-base drilling mud is given special emphasis, especially as regards deep wells where the permeability of the producing zone is low. This need for haste arises from the tendency of an impermeable filter cake to form on the sand face which is very difficult to remove even with acid with the result that the initial productivity is much less than it should be. Data are cited to show that when the producing zone is drilled into and completed in 10½ days the productivity was distinctly higher than when completion took 20 days. These results strongly suggest the desirability of speeding up the drilling in time as much as possible if a water base mud is used. Inclusion of coring, formation testing, and other time-consuming work in a drilling in program should be considered only if the information to be gained justifies both the cost of the additional work and the damage done to the productivity of the well. The results also suggest the further development and application of the oil base drilling fluid procedure, particularly to sands of low permeability.

A Practical Evaluation of Cement for Oil Wells—R. Floyd Farris, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

A series of special tests was conducted on five wells in the Gulf Coast of Texas and Louisiana at a time immediately after completion of drilling operations and before cementing of the oil string. The purpose of these tests was to determine the stabilized surface mud suction and bottom-hole temperature at conditions simulating drilling operations, the rate at which bottom-hole teemperature increases when circulation is stopped, and the bottom-hole temperature before and after cementing operations.

These wells ranged from 5,310 to 10,924 feet in depth. Measurements were made on mud circulating temperature, bottom hole temperature, and the temperature gradient. This data afforded information on the magnitude of the pressure and temperature increase on cement slurry as it moves down the pipe.

The idea of obtaining this information is to have something to go on in making a consistometer test on the cement which is to be used in a well where the temperature gradient is reasonably well known. The consistometer test is made under temperature and pressure conditions simulating those of the well, and placement time can then be closely figured. For this purpose the tables and charts given in the paper should be very useful to the engineer in charge of well-cementing jobs.

The paper has shown: 1, that high bottom-hole temperatures do not exist during normal cementing operations; 2, that the effect of pressure on cement is considerable and actually overshadows the temperature effect; 3, that it is possible to duplicate approximately actual cementing temperatures and pressures in the laboratory and obtain results which have a close relation to cement pumpability; and 4, that the results may be expressed in a form readily applicable to the problems of the field engineer.

Some Factors Controlling the Pumping Time of Oil-Well Cements—Glen R. Neighbors and Sylvan Cromer, in PETROLEUM TECHNOLOGY, November 1941. I.P. 1399; 6 pages.

High subsurface temperatures and pressures are making cementing operations more difficult as deeper producing horizons are being sought. Recorded bottom-hole temperatures above 200° F. and pressures in excess of 12,000 lb. per sq. in., obtained by combining hydrostatic and pump pressures, are not uncommon. Insufficient time is available for proper placement of standard Portland cement, because of the shortened setting time produced by these excessive temperatures and pressures, there-

AQUAGEL IN DRILLING MUDS ASSISTS IN OBTAINING SATISFACTORY CEMENT JOBS

A good mud having a low water loss is essential in securing a satisfactory job in cementing casing.

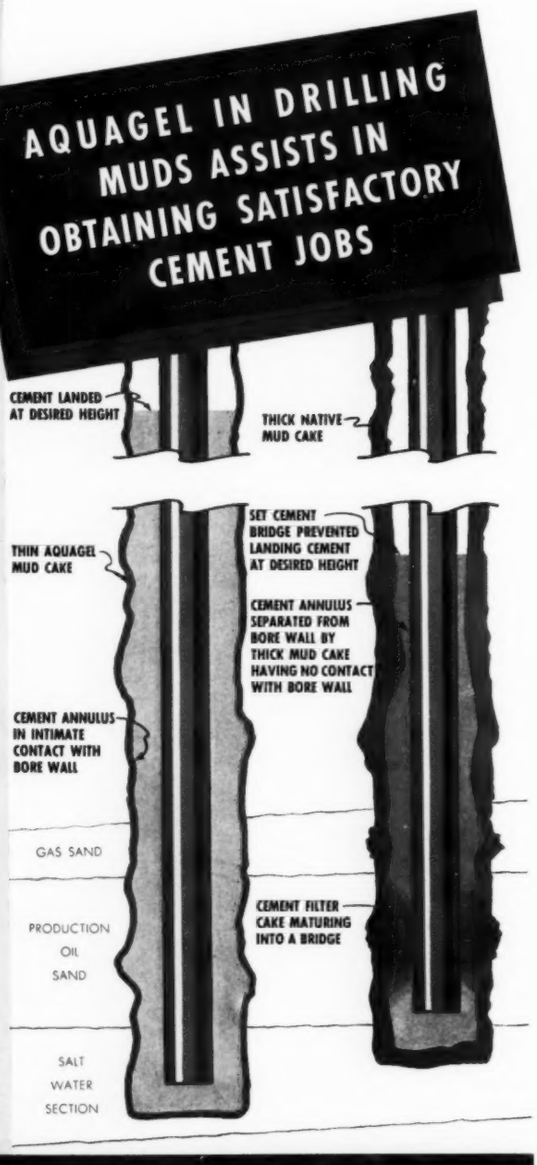
The mud cake on the walls of the hole should prevent infiltration of water when cement is pumped back of the casing. If this is not the case, water from cement will immediately filter into the formation—dehydrating the cement and causing it to set very rapidly and possibly bridge the hole—in which case the cement cannot be pumped beyond this point.

In a hole drilled with a poor mud, it is almost essential to ream in order to expand the size of the hole and thereby reduce the hazard of landing the casing at the required depth. However, when this is done, infiltration immediately starts.

A hole in which colloidal mud forms a thin, impervious cake (AQUAGEL—and BAROID if required) of suitable characteristics to meet the requirements of a particular well, will require no reaming. Therefore, the mud cake is not disturbed when the cementing operation is started. Water from the cement will not be able to escape into the formation and the original viscosity of the cement will therefore be preserved, enabling the slurry to be pumped as high up back of the casing as desired. A better bond between casing and hole is thereby attained.

AQUAGEL in both drilling mud and cement has many advantages which assist in obtaining satisfactory jobs.

PATENT LICENSES, unrestricted as to sources of supply of materials but on royalty bases, will be granted to responsible oil companies and operators to practice the inventions of any and/or all of United States Patents Nos. 1,575,944; 1,575,945; 1,807,083; 1,991,637 and further improvements thereof. Applications for such licenses should be made to Los Angeles office.


CEMENT LANDED AT DESIRED HEIGHT
THICK NATIVE MUD CAKE
THIN AQUAGEL MUD CAKE
SET CEMENT BRIDGE PREVENTED LANDING CEMENT AT DESIRED HEIGHT
CEMENT ANNULUS SEPARATED FROM BORE WALL BY THICK MUD CAKE HAVING NO CONTACT WITH BORE WALL
CEMENT ANNULUS IN INTIMATE CONTACT WITH BORE WALL
GAS SAND
CEMENT FILTER CAKE MATURING INTO A BRIDGE
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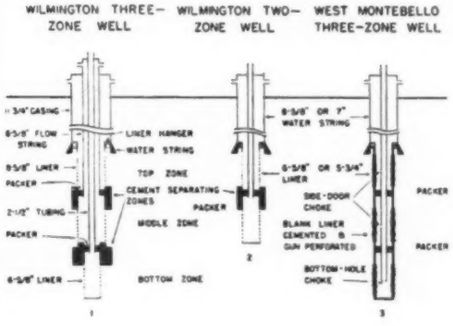
fore special types of cements have been developed to overcome these difficulties. From the standpoint of placement, the ideal slurry would be one that would remain fluid long enough to be placed, then harden rapidly, so that there would be a limited amount of contamination and the well could be placed on production in a minimum of time. It is highly desirable, therefore, that some method be devised to measure accurately the time that any slurry will remain in a fluid state while being pumped into the well.

The authors have devised and tested a method for the purpose. It consists of an apparatus similar to a Halliburton consistometer, or thickening time tester, except that it is designed to work under pressure at controlled temperatures. Temperature is the most important factor; fluidity may be reduced 96 per cent at 270° F. in some cases. Pressure is also important; the fluidity time may be decreased 15 to 25 per cent at 3,000 pounds per sq. in. It appears that results obtained with an apparatus of this type should be quite applicable to cementing problems.

OPERATION

A Review of Multiple-Zone Production in California—Robert F. Cory, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

When several productive zones are present in a field, the wells should be drilled so that the production from each zone can be controlled without affecting other zones. The differences between zones in pressures, gravity and value of the oil, gas-oil ratio, edge-water conditions, sand production, and other factors make this desirable.



The conditions necessary to insure the practicability of multiple-zone wells are fairly rare. In general, California practice indicates that separate wells to each zone are to be preferred to multiple-zone wells because of additional recovery and fewer operating difficulties.

The primary reasons for the use of multiple-zone wells, in almost all cases, have been limited space, offset requirements, and increased potentials per well.

In general, multiple-zone wells are recommended:

1. When most of the recovery will be by natural flow (perhaps aided by repressuring), the pumping life short, and the field deep.

2. When the energy of one zone can be used as a natural gas lift for oil from another zone.

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But while we're giving the "cream" of our oil supplies to the war effort, we are also making regular gasoline. For every gallon of 100-octane gasoline, there is produced from 5 to 16 gallons of automobile fuel from the same basic stocks.

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3. When space is limited and the number of wells is restricted.

4. When the establishing of high gas or oil potentials per well is important.

In most cases in which a multiple-zone well is desirable, a two-zone well is to be preferred to the three-zone well. The advantages of a three-zone well over a two-zone well are likely to be more than offset by the difficulties inherent in the more complex installation.

Multiple-Zone wells have been used principally in the Wilmington and West Montebello fields. Schematic sections of wells in these fields are shown in the accompanying sketch.

The author points out the difficulties as well as the advantages. The chief problem in drilling a multiple-zone well is the separation of the zones by cement outside the liner. The best method of cementing depends upon the special conditions found in the field and well. Recementing is sometimes necessary, but the majority of the cement jobs give no trouble.

The production problems are more serious. Packers give trouble by leaking or failing to set. When sand is produced, sand blasing of tubing and casings will occur. Also, a few feet of packed sand almost can prevent removing a packer.

Repairs are difficult and expensive. In short, although multiple-zone wells may be economically desirable, they are troublesome mechanically.

Productivity of Oil Wells and Inherent Influence of Gas-Oil and Water Saturation—R. V. Higgins, before AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, PETROLEUM DIVISION, Los Angeles Meeting, October, 1941.

Within the past decade the attention of petroleum engineers has been directed with growing emphasis toward evaluating individual well characteristics and their trends, as a necessary part of the technique of securing maximum economic recovery of developed oil measures. This report of investigations discusses briefly many of the factors which have progressive effects upon well capacities, and treats in detail a method of quantitatively estimating the influence on well productivity of the two factors, water saturation and gas-oil ratio.

The correlations obtained in quantitative treatment of these two factors suggests that the method can be an aid in indicating: (1) whether water entering a well is coming from a part of formation that can be cemented off without decreasing the well's oil productivity; (2) whether the gas flowing from a high gas-oil ratio well is coming in quantity from a distinct gas sand that might be cemented off or is flowing with the oil through the oil producing section of the formation; and (3) whether, after a well has produced for a year or more, the sands have clogged by an increase in water content or by the deposition of solid particles, such as salts, insoluble hydrocarbons, or silt. The correlations presented also may be found of value in predicting roughly the decline of individual well productivities with decline in formation pressure, and may thus find application in connection with well spacing studies and estimation of reserves. Corollary results include a more generalized method of predicting, without empirical curves, the probable productivity of a well when the water saturation and average permeability of the productive formation are known.

Field Application of Core Analysis and Depth—Pressure Methods to the Determination of Mean Effective Permeability—N. Van Wingen. Before AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, PETROLEUM DIVISION, Los Angeles Meeting, October, 1941.

This paper shows how to correlate core analysis with data from other sources, if the laboratory data are compensated to allow for the presence of connate or residual water. The indicated effective sand permeabilities can also be estimated from analytical studies of field-depth pressure measurements, using two methods: the time rate of pressure build-up after a well is shut-in from a steady state of flow, and the direct measurement of a steady state of flow and the corresponding equilibrium pressure. The correlation is exemplified by data from two wells:

	Well A	Well B
Estimated mean effective permeability from core analysis data corrected for the effect of connate water (method I)	3.20 MD	5.25 MD
Mean effective permeability based on rate of pressure build-up (method II)	2.04 MD	3.77 MD
Mean effective permeability based on the productivity index (method III)	2.18 MD	3.92 MD

The satisfactory relative agreements indicated for the results as obtained by the various methods would seem to offer valid proof that even the most simplified analytical treatment of a reservoir problem can lead to results of commensurate accuracy, provided the field application is confined to areas which meet at least the essential premises upon which such treatment is based.

Development of Radioactivity Well-Logging Through Casing—William L. Russell, in MINING MAGAZINE, Vol. 31 (1941), No. 9, pp. 457-458; 464.

The Seminole region of Oklahoma affords an excellent sample of the way in which radioactivity surveys can help the oil operators. Now that the Wilcox production is nearly exhausted, and oil production has been found in the Pennsylvanian sandstones, the oil operators are naturally anxious to plug back their wells and gun perforate the casing opposite the Pennsylvanian oil sands. The trouble is that owing to the lack of reliable well logs, no one knows where the casing should be gun perforated. The advent of radioactivity surveys has fortunately removed these difficulties, and it is now possible, by logging through the casing, to determine the exact position of all the Pennsylvanian oil sands.

The present type of instrument now used for this kind of well surveying is a long metal cylinder containing a mixture of gases under pressure, which is ionized by gamma rays from formations transversed by the instrument as it goes down the hole. The weak currents caused by this ionization process are amplified at the surface and produce a log that indicates the nature of the formations. Contacts or changes in lithologic character can be accurately located within two feet, whereas the sample lag of drill cuttings under even the best conditions is very much greater.

It is of interest to note that radioactivity logs show that if the operators had gun perforated the casing at the depths where the best available data, including sample logs, indicated the oil sands were present, they would in some cases have missed the sands entirely.

Radioactivity logs are especially useful in the rather numerous cases where oil occurs only in the uppermost portions of the oil sand, with salt water

below. In such cases, gun perforating without accurate logs would result in expensive squeeze jobs, due to encountering salt water in the lower parts of the sand, but by the use of radioactivity logs the operators are enabled to hit the exact top of the oil sand in every case.

Although so far most of the radioactivity surveys have been made to determine where to gun perforate, this is by no means the only use of the process. Radioactivity logs may also be used to map subsurface structure for deeper drilling. By making radioactivity logs through the casing, it is possible to select the exact top of the structure. Other possible uses of radioactivity logs are in obtaining good correlations, making structure sections, and in determining the exact depths at which faults intersect the wells.

NATURAL GAS

Geochemistry of Natural Gas in Appalachian Province—Paul H. Price and A. J. W. Headlee, in BULLETIN AMERICAN ASSOCIATION PETROLEUM GEOLOGISTS, Vol. 26 (1942), No. 1, pp. 19-35.

As has been known for some time, the thermal value of natural gas tends to vary from one locality to another. In past years the West Virginia Geological Survey has been collecting data on these variations in the Appalachian area and more especially in West Virginia and an isothermal value map has been prepared, which shows that the high values parallel the Pittsburgh-Huntington basin and are located in its central part. The thermal values decrease and approach pure methane from the central part of the synclinorium toward the Appalachian structural front, also toward the Cincinnati arch, and toward the northern and southern ends of the basin. Extension of the iso-thermal value lines across Lake Erie into Ontario indicate the possible presence of oil and gas beneath the lake.

From their studies the authors arrive at some interesting conclusions, regarding the distributional variations in a reservoir and the positions of gas, oil and water in relation to each other. Methane decreases, ethane and higher boiling hydrocarbons increase toward the oil. The gasoline vapors increase to a maximum and then decrease as the oil is approached, provided that the oil is in quantity and in a restricted area. The water vapor in the gas increases as the liquid water level is approached. A quantitative relation may subsist between the amounts of the hydrocarbons in natural gas and in oil in a reservoir. Near-surface gases are mostly "methane type" gases. The nitrogen content varies widely in different parts of the region, although there is a systematic and a regional variation; hydrogen sulphide and carbon dioxide occur in quantity in the older producing formations.

It is suggested that after cessation of vigorous bacterial decomposition of buried organic matter, the methane produced in this action and the reduced organic matter have reacted through a long time to approach an equilibrium mixture of the hydrocarbons that occur in oil and gas. The quantity of each of the hydrocarbons in the mixture would depend on the relative quantities of methane and organic matter that have reacted. Temperature and pressure change would be mildly influential and the composition of the petroleum would be affected by the nature of the organic

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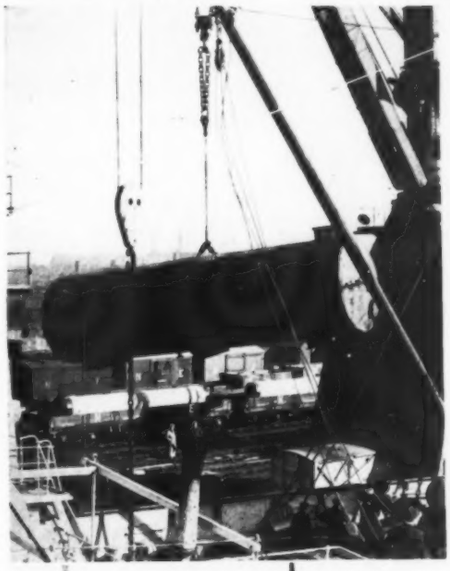

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matter and the age of the oil. (In substance, this is a distinct contribution to the theory of the origin of oil.—Ed.)

REFINING

Ignition Accelerators for Compression-Ignition Engine Fuels—J. S. Bogen, before SOCIETY AUTOMOTIVE ENGINEERS, Detroit Meeting, January, 1942.

The increase in the use of modern high-speed Diesel engines for commercial and military vehicles has created a demand for a volatile high cetane Diesel fuel. The requirements for such a fuel is placing a severe demand on the modern refiner for this type of fuel, especially in districts, e.g., California where the straight-run fuel has an ignition quality below that required by the engines.

An inquiry addressed to engine manufacturers has indicated that if the cost of Diesel fuel should rise 12 percent, the Diesel engine would probably lose its advantage over the gasoline engine. This leaves very little margin within which to use expensive refining processes in turning out the type of Diesel fuel demanded. It also becomes necessary that only a single grade of fuel be tolerated in order that distribution costs may be kept at a minimum.

The chief stumbling blocks are cetane number and ignition quality; for the cetane number the military authority has fixed a minimum of 50.

The author presents a survey representing practically all producing fields in the country; 26 percent of the Diesel fuels tabulated are below 50 cetane number. The refiners in these areas who undertake to manufacture Diesel fuel that meets the requirements will have to take special measures in processing this product.

Today there are two situations which face the refiner whose fuel does not meet ignition quality requirements. Either the fuel is just a few cetane numbers low or there is a considerable margin between the requirement and the cetane number of the stock, such as in the case of recycle material. Both of these difficulties may be overcome by such refining processes as solvent refining, hydrogenation, or blending with high cetane stock. In most cases these practices are prohibitive in cost. If the military demands for high cetane Diesel fuel are sufficient, they may nullify the latter conclusion for the duration; however, when the war is over, the refiner will be faced with supplying fuel at reduced prices. A number of refiners do not find it advantageous to produce Diesel fuel since they can obtain approximately the same price for burner oil without the necessity of maintaining such strict specifications. In addition, the refiner supplying Diesel fuel is usually called upon to maintain an expensive technical service organization to care for the complaints which usually arise from faulty engine usage.

In view of the unfavorable costs of special refining practices, attention is naturally directed to ignition accelerators, especially to ethyl nitrate commercial amyl nitrate, isoamyl nitrate and acetone peroxide. Among these amyl nitrate is the most likely to be used because it is the only one that has had any commercial development at the present time. The cost of increasing cetane with an accelerator will depend on the susceptibility of the stock to the accelerator chosen; the average cost will probably be about $0.001 per cetane number per gallon.

However it is found that ignition accelerators have certain drawbacks. They tend to reduce the flash point below legal limits; they increase the Conradson carbon of the 10 percent bottoms, but without materially increasing carbon in the engine; fuels treated with large amounts of accelerator show poorer economy, and they have little effect on starting ability regardless of quantity added.

It is doubtful at this time whether or not ignition accelerators can be economically justified. West Coast fuels will need their cetane number increased by some method and it would seem most practical to use a combination of solvent extraction and small quantities of ignition accelerators. The solvent refining process will increase the ignition accelerator susceptibility of the fuel markedly. It will be approximately one year from the time a commercial demand arises before amyl nitrate will be available in commercial quantities.

The paper concludes with an extensive bibliography on ignition accelerators.

New Lubricating-Oil-Decolorizing and Clay-Activating Process—W. B. Chenault and A. E. Miller, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

The newness of the process described by these authors resides in an apparatus and means for ef-

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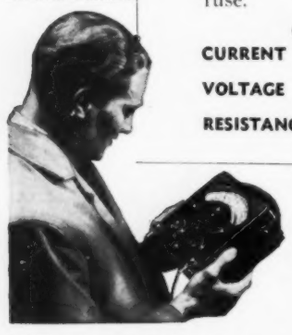

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fectively regenerating the clay by extracting the absorbed coloring matter by means of a solvent, instead of burning the spent clay in a furnace. The process has attained commercial success at the Wellsville, N. Y., refinery of the Sinclair Refining Co., where it is used on Pennsylvania type oils, though laboratory tests show that it may be successfully applied to other types. The clay used at Wellsville is a synthetic product known as Magnesol, and is described as a very pure form of hydrous magnesium silicate.

The process in outline is as follows: the oil to be decolorized is mixed with the oil and the amount of the clay that by experiment has been found sufficient for decolorizing the oil to specification. Some naphtha ("300/400" grade) is added as a diluent. The mixing is done at 190°-200° F. From the mixing tank the slurry goes through a pipe-still heater operating at an outlet temperature of 400°-415° F., from which it is flashed in a distillation system in order to remove the naphtha diluent. The bottoms from this distillation system, consisting of a slurry of clay and decolorized oil, is filtered, and the filter cake is washed with naphtha. After these operations have been completed, the deoiled cake is slurried with naphtha into a mixing tank, where acetone in an amount equal to 19 or 20 per cent of the liquid portion is added; the clay content amounts to 11 to 14 per cent; the extraction temperature is 90°-100° F. From the extraction tank the mixture goes to another set of filters where the regenerated clay is separated and slurried with naphtha back to the first mixing tank to begin another cycle; the filtrate is run through a solvent recovery unit to recover the acetone. The number of times any one charge of clay can be reused depends on its decolorizing efficiency. At Wellsville the clay is operated through about 15 cycles, or until the efficiency has dropped to around 80 to 85 per cent of the efficiency of new clay. In some instances the clay could be reused 29 times. The average throughput of charging stock of all grades is 1030 bbl. per ton of new clay, but with some oils it is as much as 1700 bbl.

Acetone losses are stated to be not more than what would be expected. The Magnesol is not abrasive like other contact clays, so the cost of maintaining lines, pumps, and other equipment is low, $0.0125 per bbl. of charge. To keep down the danger of explosions, many of the operations are carried out in the presence of an inert gas (flue gas). The process is flexible, handling oils from 150 neutral to heavy cylinder stocks.

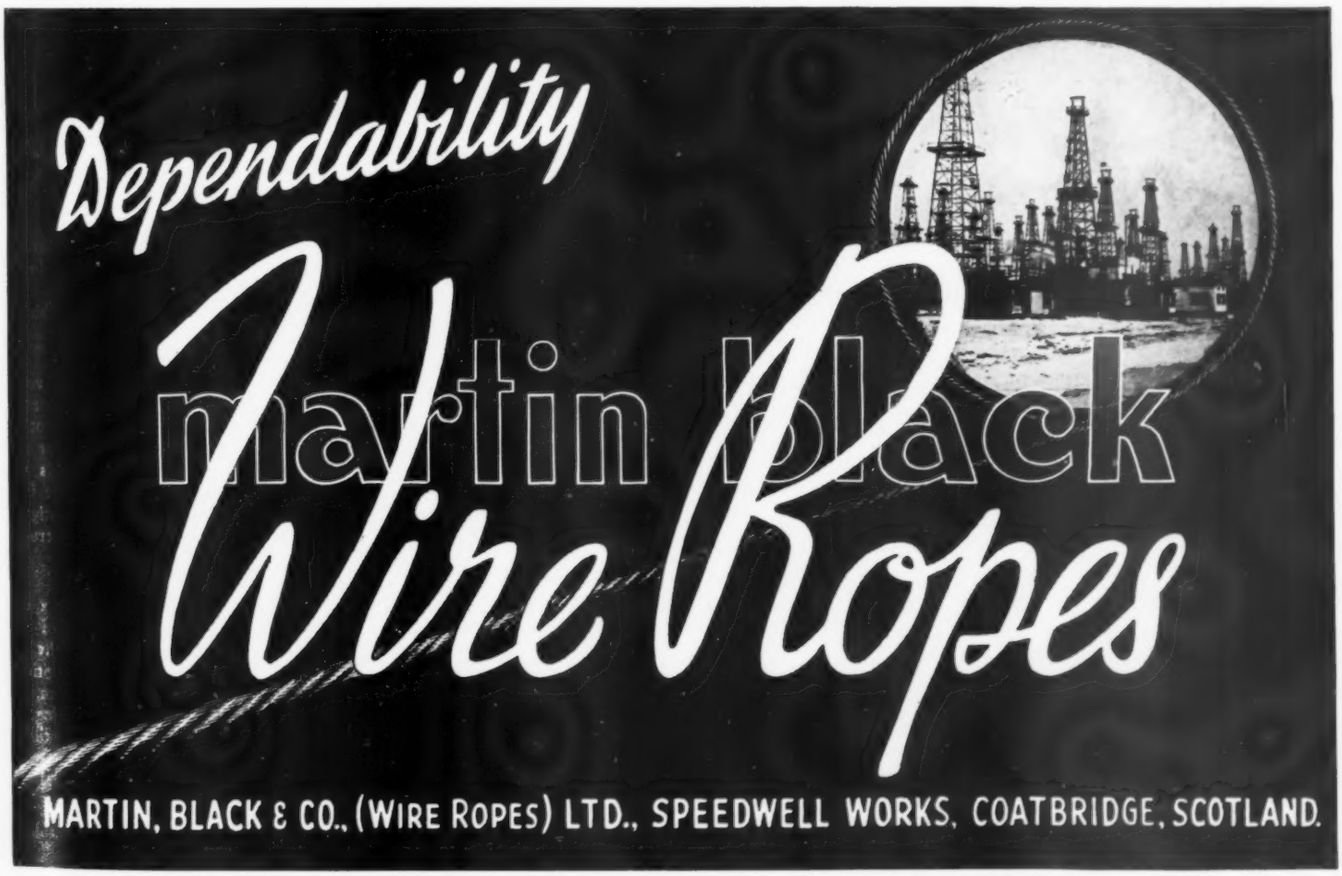
PHYSICS

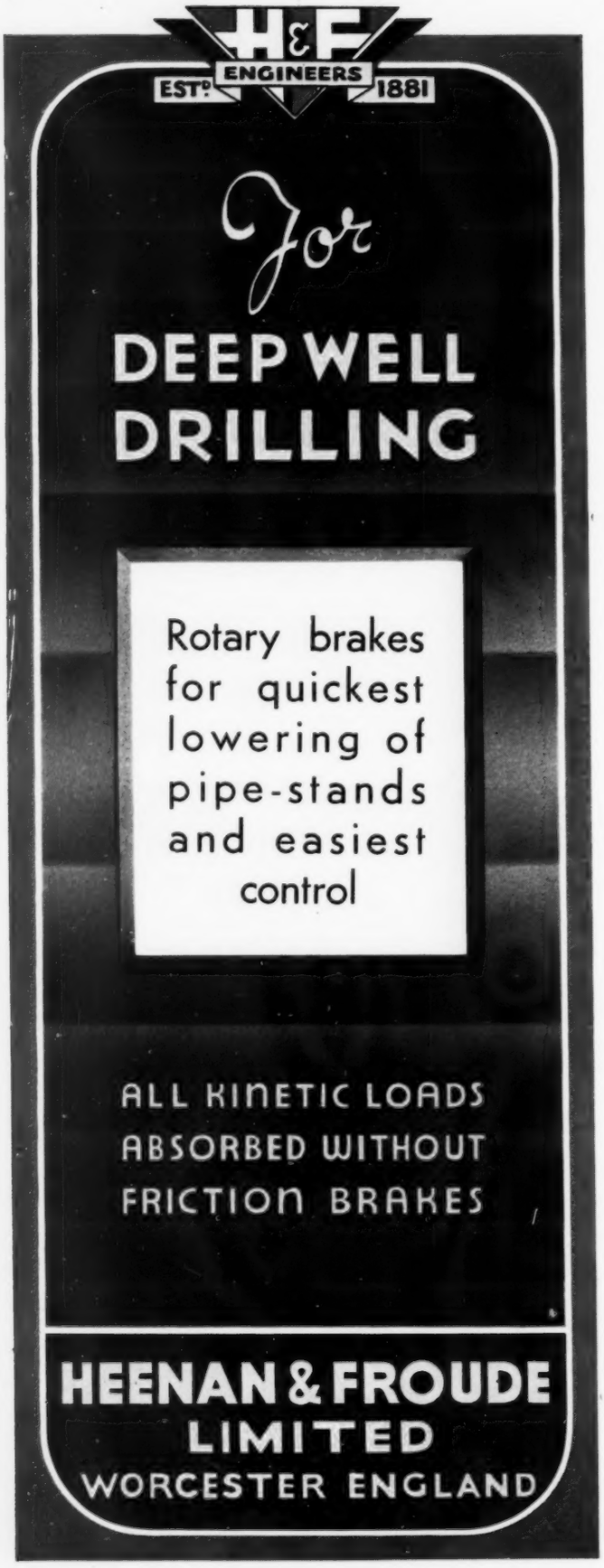
Spectrophotometric Characterization of Lubricating Oils—C. R. Johnson and Edward A. Garcia, in REFINER, Vol. 20 (1941), No. 12, pp. 72-73. The authors propose a convenient and exact method for the spectrophotometric characterization of lubricating oils. The method consists of measuring the oil's transmittance of light by means of a Coleman model 10-S-30 spectrophotometer. The operation consists in a reversal of the usual procedure for determining transmittance at a given wave length of light and finding instead the wave-length, S, corresponding to the transmittance of a reference liquid (Squibb's clear heavy California mineral oil); when percentage of transmittance is plotted against wave lengths, each sample of oil traces a characteristic curve by which the oil may be identified.

When a more complete color specification is required an oil may be described by its transmittance of visible light. Spectrophotometers such as the Coleman and the Beckman instruments, which incorporate monochromators, offer a simpler, more exact and more rational method of expressing the color of oils than any instrument using colored filters (such as the Lovibond, which should now be abandoned). In fact, it is possible to describe the color of an oil fully and exactly by obtaining complete transmittance vs. wave length curves covering the entire visible spectrum and extending into the ultra-violet and the infra-red, but for practical purposes it will be sufficient to describe the oil in terms of a few primary colors. On this basis the authors elect to use for the purpose of color analysis 30 millimicron bands of violet blue, green, yellow and red light of average wave lengths 410, 460, 530, 580 and 650 millimicrons respectively.

Surface Energy of Lubricating Oils—L. A. Steiner, in PETROLEUM, Vol. 4 (1941), No. 6, pp. 123-127.

"Surface energy" is here used as a better term for what has been called "surface tension." It is a property of matter which has been suggested as a guide to changes during the ageing and refining of oils and is evidently closely associated with the "oiliness" of lubricating oils.





Heretofore, studies on surface energy have been mostly conducted at room temperature. The author has developed a simple and rapid method for studying the surface energy of oils over a temperature range up to 100° C.

In this method the time of rise of a cylindrical air bubble in a narrow tube is determined, in a manner similar to that followed with the Steiner viscometer, but with the difference that relatively wide tubes are used with the viscometer to enable the influence of surface energy to be neglected. But when using narrow tubes (3 to 4 mm. diameter), the influence of surface energy upon time of rise is some ten times as great as that of viscosity. By suitable procedure it is possible to measure both the viscosity and the variation of surface energy with temperature. The method of calibration is briefly described, and a high experimental accuracy of ± 0.03 erg/cm.^{2} is established.

The method of determination is a dynamic one. Within certain limits it is also possible to measure variations developed with time. Thus a higher surface energy was recorded in the case of an oil when measurements had been made over a prolonged period at 30° C.

Six widely different oils were examined between 20° and 100° C. The deviation of the relationship from a straight line increases with increasing viscosity. Winchester and Reber have obtained a straight line relationship for highly viscous oils between 80° and 320° C. The author's experiments show that a curvilinear relationship is given by more viscous lubricating oils below 100° C. In one case a slight but quite definite change in direction of the curve was observed. The total surface energy, as derived from the thermodynamic considerations, was likewise calculated.

It is well known that all lubricating oils undergo a visible, or otherwise detectable change in structural form at temperatures below 0° C.. in exceptional cases also between 0° and 20° C.

The curved course of the free and total surface energy gives us some justification for concluding that the individual components form a complete mutual solution at above 100° C. only, while they exist at lower temperatures in a transition stage between complete solution and separation.

The six oils under study had surface energies ranging from 20 to 35 erg/cm.^{2}, with viscosities varying from 10 to 10,000 centistokes.

BOOKS

Stratigraphic Type Oil Fields—A Symposium of 37 papers by 52 authors, edited by A. I. Levorsen assisted by N. Wood Bass, Ross L. Heator, W. S. W. Kew, W. Perry Olcott and Theron Wasson; published 1941 by AMERICAN ASSOCIATION PETROLEUM GEOLOGISTS, Tulsa, Oklahoma, 900 pages with numerous illustrations, $5.50.

As the editor of this book remarks in his preface, the backbone of the literature of petroleum geology is a description of an oil field—its history, its geology, its production and its economics. New principles on which to base future oil discoveries depend much on an understanding of the past experience which has been put on record.

The Research Committee of the Association has already developed two volumes of Symposia that assemble a large amount of this kind of descriptive material; one of these is "Structure of Typical American Oil Fields" and the other is "Problems of Petroleum Geology." The present volume is a third member of this valuable series. Whereas the first volume dealt largely with oil fields where structural features provide the conditions for oil accumulation this one is concerned primarily with reservoirs that owe their origin mainly to stratigraphic circumstances, in other words, to stratigraphic traps rather than to structural traps.

In pursuance of their object the editors have succeeded in assembling a collection of 37 papers, each of which gives a comprehensive description of an oil field located over a purely stratigraphic trap or one where stratigraphy is the main and structure a minor characteristic. The fields selected for description are located in California, Colorado, Kansas, Kentucky, Louisiana, Michigan, Montana, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia and Wyoming. This wide variety gives petroleum geologists and students a broad view of stratigraphic traps as they are now known and are being exploited. Professionals as well as students may read and study this volume with interest and professional profit.

Besides the 37 papers there is provided a copious bibliography of articles describing stratigraphic types of oil fields.